athletes, respectively. However, this limit is criticized as being too high. The International Olympic Committee has now approved RhEPO tests—they combine a urine-based method developed by a French laboratory and a blood sampling control devised in Australia. The introduction of blood sampling and tests for RhEPO constitutes a major step forward in the effort to curb the use of performance enhancing drugs (Koppel, 2000).

Nevertheless, there are other methods of simulating altitude, or otherwise stimulating red blood cell production. Igor Gamow, presently at the University of Colorado in Boulder, invented a device capable of saving mountain climbers from altitude sickness. Essentially, an ailing climber crawls into a bag and seals it shut, then the bag is inflated and pressurized. This has the effect of bringing the climber down from altitude to sea level while still on the side of a mountain. Gamow was also familiar with the use of hypobaric chambers in which the pressure can be reduced to below that at sea level, and he had contemplated the possible training effects from using them. Intrigued by the possibility, the author encouraged him to create a chamber that could be used by endurance athletes living at sea level to study the effects of sleeping high, and training low (be careful what you wish for). The altitude bed has been successfully used by endurance athletes, and is advertised on the web (altitudetraining.com). At night, an athlete can sleep in atmospheric conditions up to 14,000 feet, and by day perform quality anaerobic work as desired.

Shawn Wallace, a British pursuit cyclist who had first used Gamow's altitude bed, then developed the altitude tent. The altitude tent is designed to fit on top of a bed and comes in various sizes. There is room enough for two, and it is transportable. More information on the tent can be found at the website (altitudetent.com). It should be noted that the altitude bed and the altitude tent use different principles to simulate low oxygen conditions. The altitude bed creates a low-pressure environment similar to that found at altitude, whereas the altitude tent provides a lower percentage of oxygen at normal atmospheric pressure. At this time, which device and method gives the most benefit is unknown.

So-called "Altitude Houses" have also been springing up everywhere, which enable athletes to live a would-be normal life while simulating altitude conditions. To diminish the supply of oxygen, altitude houses sometimes use a greater than normal percentage of nitrogen in their artificial atmosphere, or alternately, the internal pressure of the house is simply reduced. A mobile unit, which puts the "Alps in a Winnebago," has also been developed in Norway (Seiler, 1997). There is now mounting evidence that "sleeping high and training low" can greatly enhance athletic performance, and not only in the distance events (Anderson, 1992).

However, the author does not advocate using any of these artificial devices or methods. Instead, national and world-class distance runners are best advised to train at altitude. As previously discussed in Chapter 3, running on long uphill grades provides a significant training benefit, and the best place to find such challenging terrain is at altitude. A synergistic training effect occurs when running on hilly terrain at altitude that cannot be duplicated by other means.

Moreover, the use of artificial devices flirts with the invisible line that separates the light side from the dark side. Clearly, the use of blood doping, RhEPO, steroid drugs, or other anabolic hormones crosses the line. The late Australian coach Percy Cerutty (1875-1975) would sometimes remind his athletes that running circles around a track was essentially a trivial pursuit, and utterly meaningless unless the activity contributed to cultivating their character (Masters, 1999). Occasionally, coaches and athletes need to step back and consider the big picture—and reflect on whether they enjoy peace of mind. Not everything in life can be measured by the stopwatch.

> ***If you follow the present-day world, you will turn your back on the Way; if you would not turn your back on the Way, do not follow the world.***
>
> —Takuan Sōhō

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PHOTO 14.1—Cathy Freeman wins the 400 meters wearing aerodynamic apparel, 2000 Olympic Games. Photo by Thomas Kienzle, from AP/ Wide World Photos.

CHAPTER 14

AERODYNAMIC DRAG AND DRAFTING

Athletes and coaches need to respect the magnitude and practical effects of aerodynamic drag on running performance. The findings of technical experts on this subject generally agree with the consensus reached amongst knowledgeable coaches. In the absence of wind, drafting a lead athlete at less than or equal to one meter of separation is worth about one second/400 meters at sea level (Kyle, 1989). The additional energy cost of leading a race is then about one second/400 meters in the middle distance and distance events. If an athlete is going to attempt to lead and win the 1,500 meters right from the gun, then he or she had better be at least four seconds fitter than the rest of the field. And the athlete would have to be about eight seconds better in the 3,000 meters, 12 seconds in the 5,000 meters, 24 seconds in the 10,000 meters, and over 1:30 in the marathon. These are large margins at any level of competition.

Frequently a runner makes a break in a race, leaving behind a pack of two or more athletes. With respect to aerodynamic drag, the athlete leading the trailing pack is on par with the runner who has made the break. However, the athletes drafting the leader of the trailing pack are gaining one free second every 400 meters in terms of their relative energy cost. Unless the runner who has made the break can accumulate and sustain an advantage at the rate of one second/400 meters over the remainder of the race, her or she will be vulnerable in the closing stages of the race to athletes of equal ability who might attack from the trailing group.

If a runner takes the lead in the 5,000 meters at two miles, leaving behind a trailing pack of athletes, then he or she needs to accumulate a lead of four seconds and/or be that much more fit than the rest of the field in order to hold off a late attack. An athlete taking the lead in the 10,000 meters at four miles needs to accumulate and/or be about eight seconds more fit than the others in the field. And a runner taking the lead in the marathon at 18 miles needs to accumulate and/or be about 32 seconds more fit than the field. This realization can have a sobering effect on athletes who have never studied the phenomenon.

Several lessons can be drawn from this information. Sometimes patience is indeed a virtue. The lead is always a temptation. An athlete should not take the lead unless he or she is ready for the responsibility and possible penalty it may bring. A front-runner is sometimes well advised to take advantage of an honest early pace and use the surge tactics or preliminary breakaway attempts of other athletes to weaken and thin the field before making a decisive break. Many runners waste precious time and energy in a race by making inconsequential

moves. Athletes will often assume the lead even when they do not intend to do anything with it, nor perhaps know what to do with it. Such theatrics may win the approval of some spectators, but they are foolhardy. However, recognize that nothing is fixed in strategy. Psychological dislocation is more important than physical dislocation, although one is generally associated with the other (Liddell-Hart, 1967). The decisive moment in a race can come in the first meter or the last.

Here is an estimate regarding the odds of an athlete winning the 1,500 meters, given a field of equally talented contestants, by attacking with:

400 meters to go—about 10%
300 meters to go—about 25%
200 meters to go—about 50%
150 meters to go—about 65%
100 meters to go—about 75%
50 meters to go—about 85%

Some of the above is due to aerodynamic drag, which becomes more pronounced as athletes move at higher speeds. For example, let's say an athlete competing in the mile drafts for the first three laps, thereby saving about three seconds worth of energy over the first 1,200 meters, and then attacks with 400 meters to go. A second athlete, who has also drafted for the first three laps, then continues to draft the new leader for the next 300 meters. This second athlete accumulates a further energy savings of .75 seconds over the next 300 meters that can be used in the final kick with only 100 meters to go.

Does this mean an athlete should let others do all the work, sit back, and wait to kick? In truth, there can be two correct answers to this question, depending on the circumstances. If a runner is relatively inexperienced and substantially less fit than others in the field, then the answer is yes. However, if an athlete is as experienced and fit as others in the field, then the answer is no. For example, an athlete who wishes to excel will often need to contribute to the pacing in order to get a qualifying time or personal record. And unless a runner is alone in having a strong kick, simply sitting and waiting will not work. A complete athlete can win from the lead, win from the surge or breakaway, or win from the kick. Not every runner will have the natural talent or versatility to be able to do all of those things. But when an athlete can do all of these things, then he or she has developed a repertoire that makes for some exciting racing.

Obviously, there is plenty of room for sound judgment and intuition when racing. Certainly, when an athlete takes the lead in the third lap of a 1,500 meters race and wins (as Herb Elliott did in the 1960 Olympic games), or strikes early in a marathon (as Joan Benoit Samuelson did in the 1984 Olympics), it generally means they have superior physical fitness, but also the intelligence and courage to match.

The additional energy cost of running into a headwind is approximately proportional to the square of the wind speed. So unless you have a good reason, avoid doing all the work leading into the wind. Instead, it is better to trade off the lead. If you face competitors unwilling to do some of the work, then sometimes it

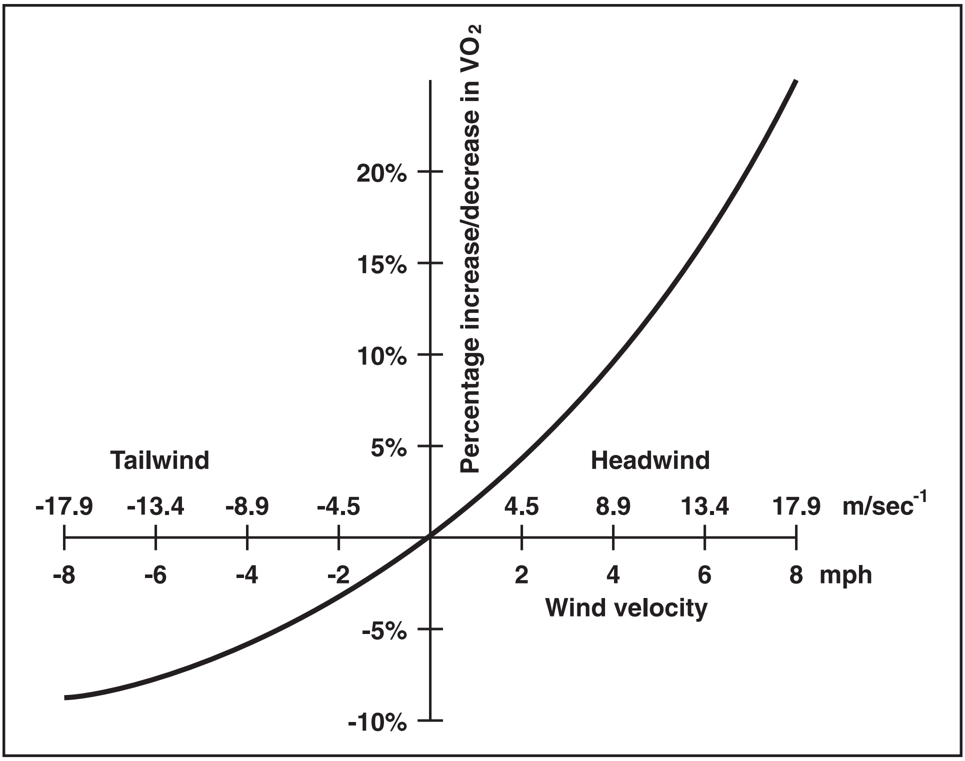


FIGURE 14.1—Change in VO_2 demand as a result of headwind or tailwind (% greater or lesser relative to calm air). Reprinted by permission, from J. Daniels, 1998, *Daniel's Running Formula*, Champaign, IL: Human Kinetics, page 184.

may be possible to move out to lane three, stop dead, and stand there with your hands on your hips. The psychological dislocation alone will probably be worth it. Wait till they go by and then sit on them. Runners are so conditioned to think they should never stop, and that lane one is the shortest course, that they sometimes fail to seize the obvious answer to this vexing problem. If the other athletes do not want to do their share of the work and lead, then sometimes you can maintain command of the race by making them lead.

An athlete can do a number of things to decrease aerodynamic drag. It is best not to run shoulder to shoulder with another athlete, as both athletes then increase their drag. It is better to run just off the shoulder of a lead runner, with the drafting athlete's left arm and leg synchronized with the right arm and leg of the lead runner so as not to make contact or impede. And if the tactical situation permits, it is best to follow directly behind one or more athletes as close as possible.

The torso generates less aerodynamic drag in the nude condition than when wearing a singlet, but obviously this is not always possible or conducive to modesty. Shorter or closely kept hair can also reduce aerodynamic drag. Accordingly, so-called "Benjamin Franklin" hairstyles can cost an athlete a healthy amount of time. However, it is possible for long hair secured behind the head to

PHOTO 14.2—Joan Benoit Samuelson waves to the crowd after winning the marathon, 1984 Olympic Games. Photo from AP/Wide World Photos.

create a more tear-dropped shape that can actually slightly decrease drag. The common practice of women to draw their hair taught about the sides of the head into a trailing ponytail is sound. Accordingly, women should not go out and cut their hair unless it pleases them to do so. However, an elite male sprinter having substantial body hair would be well advised to consider the body shaving practiced by some swimmers.

Principles of Aerodynamic Drag

There are two types of aerodynamic drag: surface friction drag, and pressure-induced drag. The portion of total drag derived from surface friction is small compared to pressure-induced drag, but still a significant factor. Pressure-induced drag is created by a cylinder shaped object—that is, the human torso and limbs—blowing a hole through the fluid we know as air. Figure 14.2 illustrates some of the phenomena associated with pressure-induced drag. The boundary layer of air separates about the sides of the runner's torso, creating a turbulent wake. This results in the creation of a high-pressure area on the front of the torso, and a low-pressure area behind the runner.

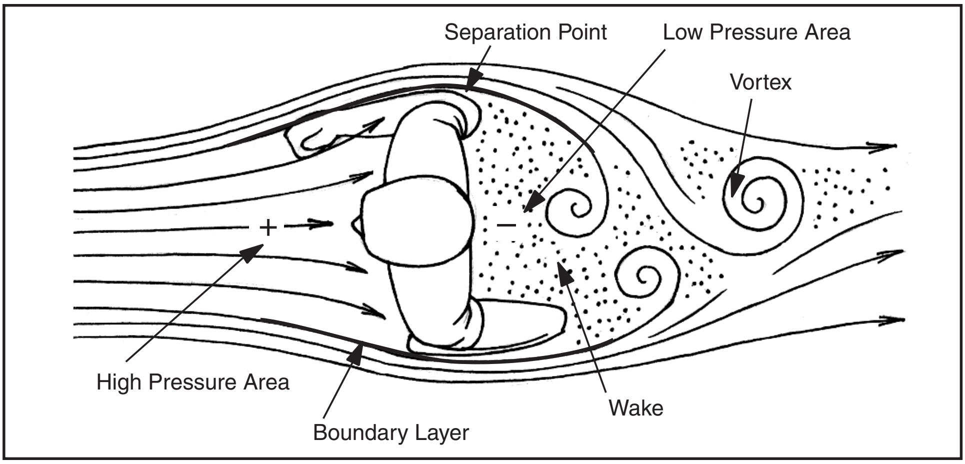


FIGURE 14.2—Top view of a runner, showing pressure-induced aerodynamic drag

Aerodynamic Drag: The sum of friction induced drag, which corresponds to the work done when a gaseous fluid (air) slows and produces heat when encountering a surface, and pressure induced drag, which corresponds to the work done in overcoming a build up of high pressure on the font of an object due to its blowing a hole in the gaseous fluid (air) and creating a wake of low pressure behind it. Pressure-induced drag is the most substantial contributor to the aerodynamic drag experienced when running. The formula for calculating pressure-induced drag is,

$$D = .5\ (p)\ (Ap)\ (Cd)\ V^2$$

D = the force of drag in Newtons
p = air density (Kg/m^3)
Ap = the projected frontal area normal to the air stream (m^2)
Cd = the coefficient of drag, (the object's aerodynamic efficiency)
V = the velocity of the object in meters per second.

The variables in the equation for calculating pressure-induced aerodynamic drag merit further consideration. Accordingly, the practical effect of changes in the air density, projected frontal area, coefficient of drag, and running velocity will be briefly discussed.

Due to the presence of lower air density at altitude, there is less of a price to pay with respect to aerodynamic drag. A performance advantage of 1.7% was observed in the sprinting events at Mexico City (Ward-Smith, 1984). At the lower speeds of middle distance and distance events (that is, six to seven as opposed to 10 to 12 meters/second), the advantage would be approximately one quarter of that experienced in the sprint events, since velocity is squared in the formula for aerodynamic drag. Therefore, you can reasonably expect an advantage relative to sea level of only about .41%. This would be worth about .98 seconds in a 4:00 mile. So, instead of an energy savings of four seconds over the mile, drafting

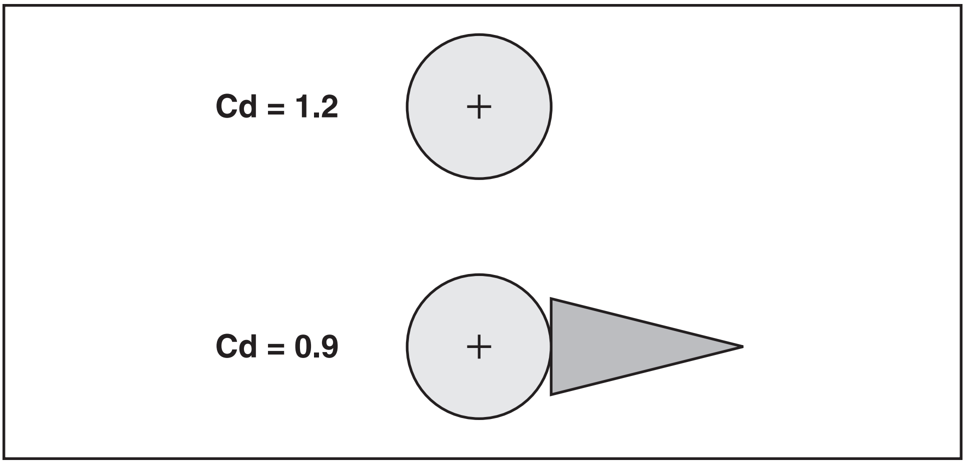


FIGURE 14.3—Adapted from Hoerner, 1965

athletes perhaps only gain about three seconds when competing at altitude. However, there is a greater penalty to pay for a misjudgment of pace and inefficient use of energy at altitude. In contrast, due to the higher air density associated with conditions of high humidity, athletes should then expect to pay a higher than normal price for leading.

The greater an individual's projected frontal area, the greater will be the resulting aerodynamic drag. In this regard, a shorter athlete with a slight build has an advantage over a larger athlete. The easiest way to reduce the projected frontal area is to draft another runner. And when confronted with headwinds, an athlete who leans forward will both reduce their projected frontal area, but also influence their coefficient of drag so as to become more aerodynamically efficient.

The coefficient of drag is a dimensionless number that expresses the aerodynamic efficiency of an object. In this regard, the human torso generally resembles a cylindrical shape, whereas the arms and legs have a more oval shape. As shown in Figure 14.3, modifying a cylindrical shape to a teardrop shape can significantly reduce its coefficient of drag and the resulting pressure-induced aerodynamic drag.

Other things being equal, the faster an athlete is running, the greater will be the resulting aerodynamic drag. Accordingly, aerodynamic drag can be a more significant factor with respect to the performance of sprinters than long distance runners, as sprinters can reach speeds exceeding 25 mph. And it is a much greater factor in the performance of speed skaters and cyclists who move at even higher speeds. In fact, about ninety percent of the work performed when bicycling on level terrain is expended to overcome aerodynamic drag.

The caveat to this discussion is that in certain circumstances the aerodynamic drag generated by an athlete can actually be reduced at higher speeds. What happens is complex, but can be simply explained as follows. When moving slowly, a cylindrical shaped object such as a runner's torso blows a relatively large hole in the fluid we know as air. The boundary layer then separates relatively

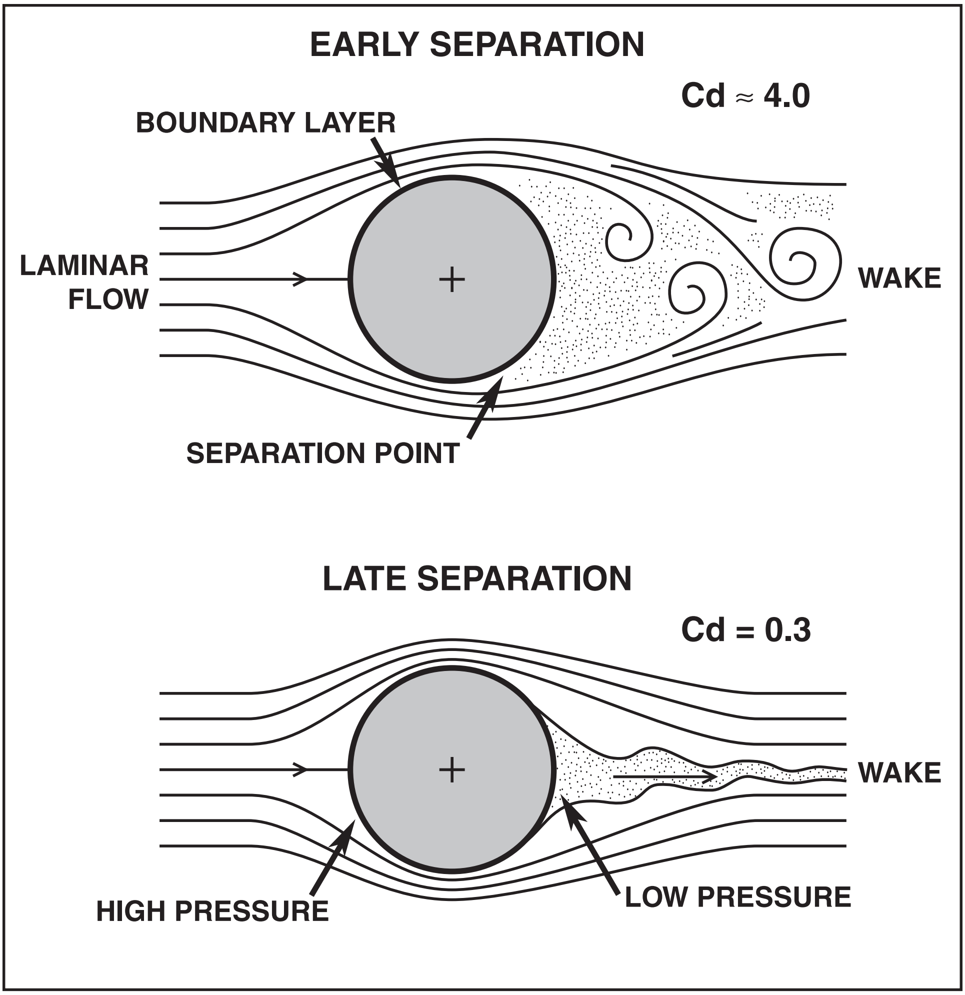
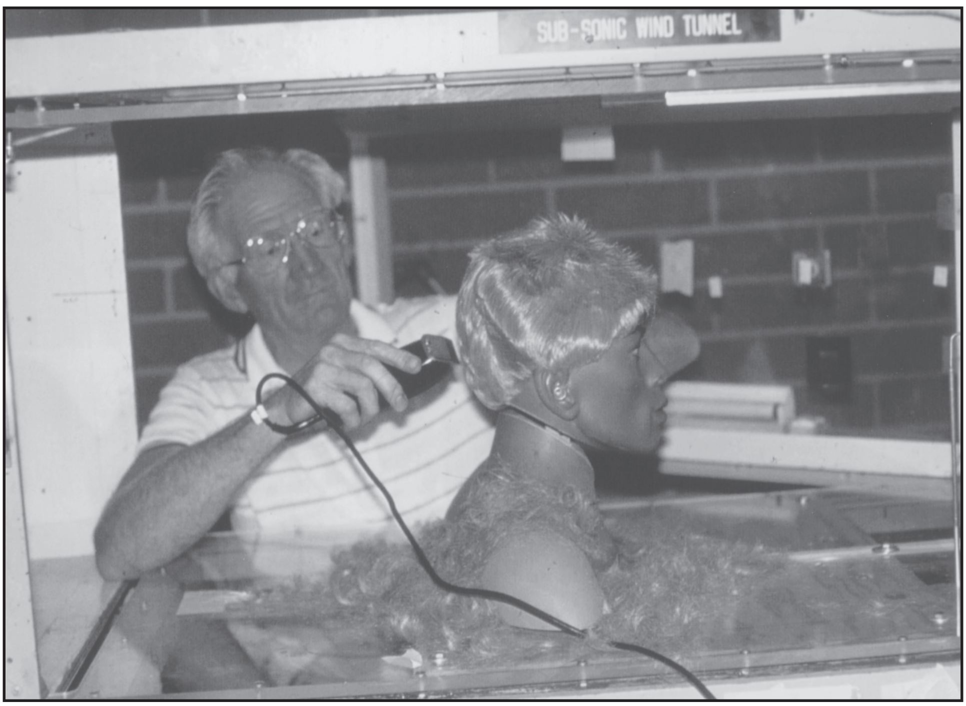


FIGURE 14.4—Adapted from Pugh, 1971

early, and this results in a large wake including random turbulence. However, as the runner's velocity increases, the boundary layer will separate later. And with the onset of fully developed turbulence, a dramatic narrowing of the athlete's wake can suddenly occur. There exists a dimensionless number called the critical Reynolds number that is associated with this threshold phenomenon. And the magnitude of the aerodynamic drag being generated can then dramatically decrease to only about 30% of its former value. Figure 14.4 illustrates the wake of two cylindrical shapes—one moving at a velocity below, and the other moving above the threshold associated with the critical Reynold's number.

Distance runners do not move at high enough speed to encounter this critical threshold, but sprinters can approach it under certain circumstances. In particular, the use of aerodynamic apparel can reduce an athlete's coefficient of drag so as to narrow the margin. However, speed skaters and especially bicyclists can move at speeds that enable them to reach the threshold with the aid of aerodynamic apparel.



PHOTOS 14.3 and 14.4—Chester Kyle preparing models for wind tunnel testing, 1986. Photos courtesy of Chester Kyle.

Distance (m)	Avg. Speed (ms^{-1})	Time Savings [s (I)]	Advantage* (m) I	II	III
100	10.7	0.01	0.1	—	—
200	10.15	0.02	0.2	—	—
400	9.12	0.08	0.7	1.9	1.2
800	7.86	0.14	1.1	2.7	1.8
1,500	7.12	0.24	1.7	4.2	2.7
5,000	6.41	0.76	4.9	11.3	7.3
10,000	6.09	1.46	8.9	20.5	13.2
Marathon	5.50	5.70	31.3	70.2	45.4

TABLE 14.1—Advantage due to a 2% reduction in aerodynamic drag, using three different equations. From Kyle, 1986.

Aerodynamic Apparel

The present rules governing competition in track and field prohibit the use of apparel to unnaturally aid performance. However, practically speaking, even small variations in apparel design and construction can affect aerodynamic drag. In keeping with the spirit and letter of the rules, athletes then have latitude, by way of selecting appropriate apparel, to make prudent decisions that can impact their performance. Generally, a singlet made from a material with a tightly woven, smooth surface or a slick sheen rendered impenetrable to air works best to reduce friction drag. These materials can cause substantial heat build-up, and so although they can be used in the sprint events, they are not normally practical for distance runners. The one-piece stretchlastic body suits worn by sprinters, particularly suits with hoods covering the head, can and do reduce aerodynamic drag. The most knowledgable person in the United States on the subject of aerodynamic drag and athletic apparel is Chester Kyle of Weed, California. He has shown that even the difference between having short hair versus long hair can decrease aerodynamic drag by two percent (Kyle, "Athletic Clothing," 1986). Table 14.1 shows the effect of a two-percent-reduction in aerodynamic drag upon running performance calculated using three different equations.

Again, friction drag is a relatively small part of the total aerodynamic drag on a runner. The primary contributor is pressure-induced drag. An unusual thing can happen when a material having a fine surface roughness is positioned in just the right places. The introduction of surface roughness with a design that is capable of creating premature turbulence, or one that otherwise prevents the boundary layer from early separation about the sides of a runner's singlet and shorts, can narrow the wake and decrease pressure induced drag. Thus, if athletes need to include a fine mesh in their singlets in order to manage expected hot and humid conditions, it can be placed along the sides and back without so adversely affecting aerodynamic drag. And a well-designed singlet can slightly decrease drag. In this regard, the mere presence of a properly placed sewing seam, or a material having the surface roughness of fine woven wool is enough to change the resulting aerodynamic drag by a significant amount (Kyle, "Athletic Clothing," 1986, Brownlie, 1992).

FIGURE 14.4

Aware of Kyle's work, the author designed a custom singlet for use by Steve Plasencia in the high heat and humidity encountered in Indianapolis during the 1988 U.S. Olympic Trials. A more radical design intended for sprinters included a dramatic V-shaped back to create a teardrop shape (See Figure 14.4). The apparel was tested on a bicycle by rolling with the acceleration due to gravity down a steep hill to attain a maximum speed of approximately 30 mph at the end of 100 meters. Most noticeable was the relative absence of turbulence, thus the pulling and flapping noise usually associated with conventional apparel was all but eliminated. The design shown in Figure 14.4 was found to be worth nearly a tenth of a second. The marketing strategy was to launch the "Godzilla Suit" at a major competition in Japan, and to create a sensation.

The author began working for Nike, Inc. as a regular employee in 1990, and later granted the company a non-exclusive license regarding certain aerodynamic apparel know-how and intellectual property. However, despite that fact Kyle, Len Brownlie and the author had shown the merit of such apparel, nothing really came of it until a decade later. By an unusual coincidence and turn of fate, Nike Vice-President Sandy Bodecker, who was aware of the research, married the Australian sprinter Cathy Freeman, and the rest is history.

Aerodynamic apparel has also had an impact on the outcome of speed-skating competitions, and the Tour de France. In this regard, the competition rules have not kept pace with the evolution of modern technology. In conclusion, aerodynamic drag and drafting can significantly affect athletic performance in the middle distance and distance events. It is important to appreciate and respect those forces which cannot be seen.

> ***Pay attention even to trifles...***
> ***Immature strategy is the cause of grief.***
> ***That was a true saying.***
>
> —Miyamoto Musashi

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PHOTO 15.1—Steeplechase action at the 2000 Oregon Track Classic, Lewis & Clark College. Photo by the author.

CHAPTER 15

THE STEEPLECHASE

The 1972 Olympic Champion in the Steeplechase, Kip Keino of Kenya, once referred to the steeplechase as a “race for animals.” In fact, the steeplechase event originated in English horse races, which were run across the countryside, using church steeples to mark the start and finish. In 1850, faced with ground conditions unfit for settling a wager by means of a horse race, Halifax Wyatt proposed instead that the matter be settled by a human footrace. The first steeplechase was conducted on a two-mile course over 24 barriers composed of hedges and water-filled ditches. The steeplechase was contested in the 1900 Olympic Games, and in 1920, the distance was fixed at 3,000 meters. In 1952, Horace Ashenfelter, an FBI agent, defeated Vladimir Kazantsev of the Russian police for the Olympic Gold Medal. Ashenfelter’s success and George Young’s Bronze Medal in the 1968 Olympic Games stand as the best performances by American athletes in this event at the international level (Hartwick, 1981).

The Need for Introduction at the High School Level

In part, the lack of American success is due to the fact that high school athletes seldom compete in the steeplechase. Occasionally, the event will be contested in an invitational meet at a facility that has a water jump. It would be beneficial for state high school championships nationwide to include a modified 2,000 meters steeplechase event. This hypothetical high school event could be run over barriers, but perhaps not include the water jump hazard. These changes would make the event easy to stage from a logistical and economic standpoint.

Prospects for the Steeplechase

Collegiate coaches will often make steeplechasers out of athletes who do not appear to be talented enough to excel at either 1,500 or 5,000 meters. However, the best steeplechasers are those with the aerobic ability to compete at 5,000 meters, but who then sharpen themselves to attain peak condition in the 1,500 and 3,000-meter events. Ideally, a male steeplechaser should be long legged, with at least a 34-inch inseam. However, others should not be prematurely ruled out, as some relatively short athletes have excelled in this event. To effectively negotiate the steeplechase barriers, the athlete must also be well coordinated, flexible, and physically stronger than the average distance runner. So rather than being a mediocre athlete, the true steeplechaser will likely be the most talented distance runner on any given athletic team.

The Steeplechase Barriers

The 3,000-meter steeplechase event requires athletes to negotiate 28 barriers and 7 water jumps. The height of the men's barriers is 36 inches, whereas the height of the women's is presently 30 inches. So the steeplechaser needs to be an excellent hurdler and capable of leading with either leg. Some runners will step on the first barrier, or otherwise step on barriers when caught in traffic and being jostled. It is far better to be safe than sorry. Athletes who hit a barrier will often have to retire from the race with an injury. The barriers weigh between 80-100 kg and do not move or deflect in the least when hit. This being said, it is normally most efficient to hurdle all of the barriers, with the exception of the water jumps.

The Steeplechase Water Jump

The men's water jump hazard is 30 inches (70 cm) deep adjacent to the barrier, and gradually decreases as it extends 12 feet beyond. The water jump hazard should be taken with a quick step. The athletes then push off from the barrier so as to land while still one to two feet from the far end of the water hazard, thus in slightly less than 12 inches of water. This cushions their landing and facilitates recovery of their running rhythm. Generally, if athletes land too far from the barrier in too shallow water, they will greatly flex at the knee and dramatically lean forwards, thus unduly lowering their center of gravity. This can cause a considerable loss of momentum, rhythm, and demonstrable speed when exiting the water jump. On the other hand, if they land too deep in the water, this will also reduce their exit speed.

Some athletes will hurdle the water hazard on the last one or two laps of the steeplechase event. Done properly, this technique can be worth five to 10 yards, depending on the quality of the field. However, if they bobble, they will be fortunate to come out even—or worse, could finish the competition sitting in the water hazard. This technique needs to be well rehearsed when athletes are fresh, but it should also be practiced occasionally when they are fatigued. However, this technique can increase the risk of injury, and is not prudent for every individual. Nevertheless, when steeplechasers are able to run the last one or two laps at 64 seconds/400 meters pace or faster, it becomes a viable option and potent competitive weapon. At this speed, the act of stepping and pushing off the barrier can be difficult to do, and can unduly slow athletes. This can prevent runners from attaining the success they might otherwise enjoy at the national and international levels. When running at a 64-second pace or faster, athletes hurdling the water hazard will actually land in nearly the same position in the water as when stepping and pushing off the barrier when running at only 70-second pace.

When teaching athletes to negotiate the water jump it can help to start with a six-by-six-inch barrier affixed to the ground in a grass field or at the head of a long jump pit. The landing area can then be marked to indicate the 12-foot line and the target landing point at about 10 feet. Over a period of weeks, this barrier can be raised to 24, 30, and finally to 36 inches (Dellinger, 1978). Alternatively, athletes can work off a 36-inch barrier from the beginning, and initially land only six feet beyond the barrier, but then gradually work their way out to 10 feet. Athletes need

PHOTO 15.2—Athletes pushing off from the water jump barrier, 1996 Penn Relays.
Photo from Victah Sailer / Photorun.

to learn to step the barrier with the toe of the shoe hanging over so they can make a quick transition as they push off and extend horizontally. When stepping the barrier, the heel should not be lower than the barrier, or steeplechasers will block themselves before they are on top of the barrier (Hislop, 1999). The University of Oregon uses a resilient plywood cover on the water jump pit to allow athletes to practice a dry landing before actually attempting the water hazard.

If steeplechasers do not have access to a facility with a water hazard, they can take a makeshift six-by-six-inch barrier to a shallow body of water, and then set it up near the waterline. Athletes can then practice hurdling over the barrier and into water. If they trip on the barrier they are not likely to become injured, rather, will fall into the water and land on the underlying sand surface. As an alternative, coaches and athletes can use a six-by-six-inch beam and two carpenter horses to make a portable barrier for use in conjunction with a long jump pit.

Prerequisite Conditioning

Again, the steeplechaser needs to be an excellent hurdler. The athlete should be taught from the start to be able to lead with either leg, and this entails being able to trail with either leg as well. It sometimes helps to do some preliminary screening of prospective steeplechasers with the use of hurdles and simple hurdle drills. However, once a group of prospective steeplechasers has been identified, they should first be given a foundation of at least one month of specific strength and flexibility work before beginning lead-leg or trailing-leg drills, or attempting to hurdle.

As discussed in Chapter 7, there is a logical progression to stretching and flexibility work. Athletes should be able to perform the basic static stretches and PNF exercises before attempting any dynamic flexibility exercises. And the latter should be mastered before they begin to practice hurdling. For the novice hurdler or steeplechaser, the hamstring stretch, the hurdler's stretch (or L7), and those stretches directed towards the adductors of the leg will normally require the most work.

The L7 position is perhaps the single most beneficial stretching exercise for the steeplechaser, both novice and master. The lead leg should extend straight out in front of the athlete's torso, and the trail leg should project at a 90-degree angle from the lead leg to form an "L" shape—a straight line drawn through the hips should intersect the knee of the trail leg. The toe of the trail leg should be dorsiflexed, and a straight line drawn between the end of the toe and the knee of the trail leg should be approximately parallel to the lead leg. Athletes should be able to sit comfortably and study in this position. It helps to lean forward and hold the stretch for 10 to 30 seconds while keeping the back straight and head up—thus leading with the chin as opposed to the forehead. Athletes should also grasp the knee of their trail leg and similarly hold this stretch position for 10 to 30 seconds and repeat. Steeplechasers can then practice leaning forward, breathing naturally, and moving their arms as when hurdling. They should alternate stretches and work on both legs so as to be able to lead with either leg in competition (Hislop, 1995). When athletes are able to sit comfortably on the floor in the L7 position and perform these exercises well, then they are ready to begin dynamic flexibility exercises.

Dynamic flexibility exercises should always progress from simple, slow movements to more complex, rapid movements. Athletes should be able to do the 100-up routine—that is, from a standing position, raise one knee above the waist while simultaneously dorsiflexing the elevated foot, then return it near to the floor without touching down for 100 reps. When they master this, athletes can begin practicing lead leg drills by positioning a hurdle against a wall, or by making a target on a wall three to six inches above a mark at 36 inches. Athletes should stand five to seven feet from the wall, advance a step with their trail leg, then raise and lead with the knee, extending their foot in a slow-motion kicking action. The lead foot should rotate approximately 45° from vertical as the knee is extended, because this will permit less clearance height of the barrier, but the knee should never fully extend or lock. When they master this, they can accelerate the action and the foot of the lead leg can perform "wall attacks"—that is, touching and rebounding from an opposing wall. If athletes fail to dorsiflex their lead foot, or leads with the foot as opposed to the knee, a box or other obstacle can be placed in front of them so that they will hit it unless the correct technique is used. Sometimes it helps to use a kicking technique when teaching athletes to lead with the knee, and the appropriate verbal cue would then be to "knee-kick." This kicking action will cause the leg to recoil, and the lead foot then returns to the track surface faster. It will also cause a so-called "delayed rear leg action," characterized by greater extension. It thus brings the torso closer to the barrier, causing a greater proportion of the stride to be in front of the barrier. All of this

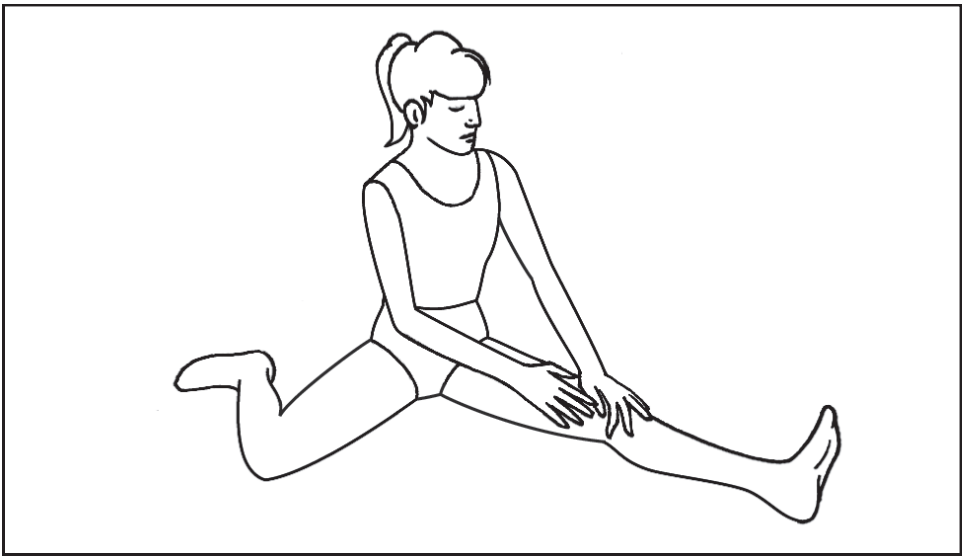

Figure 15.1—The L7 position

helps to speed and facilitate the clearance of the athletes over the barrier. The steeplechaser should also focus on cultivating balance and plantarflexion during this exercise.

A variety of exercises or devices can be used to specifically condition the lead leg, including: L-sit pull-ups, inverted sit-ups, sit-ups in which athletes raise torso and legs simultaneously and clap hands behind their legs, Anisimova drills, as well as the use of surgical tubing, ankle weights, and weighted shoes. Further, athletes should be capable of the “50-ups” routine with the trailing leg. In this regard, athletes should form a window with the trailing arm while raising the trailing leg up and out to the side at approximately 90° as if clearing a hurdle. As they raise the trailing leg, the foot should be dorsiflexed and cocked to the side, but kept as close as possible to the buttocks. The knee of the trailing leg should remain slightly higher than the trailing foot. The trailing leg should not get behind the hip, since that can induce rotation. When sufficient levels of flexibility and strength have been acquired, continuous trail leg exercises over the edge of a hurdle can then be done to good effect, and the exercise can become more vigorous with improved skill levels. For example, athletes can place a 36-inch hurdle three to four feet from a wall, and stand beside it facing the wall with the heel of the trailing leg slightly forward of the plane of the hurdle barrier. They can lean forward and put their hands on the wall, extend the trail leg behind as if completing their stride, then bring the trailing leg forward over the hurdle in the L7 position. The athletes should be up on the ball of the lead foot while bringing the trail leg over the hurdle. They should then work to increase the accuracy and speed at which the trail leg encircles the hurdle. Steeplechasers will eventually be able to stand next to a hurdle without substantially bracing themselves and perform trail leg drills.

In training abduction of the trail leg, variations of the following exercise can be useful: Athletes may lie on their sides upon the floor, or assume the hands and knees position, then extend from the hip and perform reps in relatively straight or circular movements with the trail leg to the side or behind. If more resistance is needed, weights or surgical tubing can be used. The use of a fixed weight and pulley system at floor level is particularly helpful in strengthening the adductors and abductors. An athlete can then move in a semicircle around the fixed position of the apparatus—that is, from a 12 o'clock to a 6 o'clock position and vice-versa. This can be done by taking one step, then performing a flexion or extension movement with the leg affixed to the pulley apparatus, then continuing by taking another step and repeating the exercise. Strength endurance activities such as running in sand, cross-country skiing, bicycling, and running in up to one foot of water along a beach can also benefit steeplechasers. Swimming the breast-stroke, or performing lead-leg, trail-leg, and other hurdle exercises in a pool can also provide a positive training effect (McFarlane, 1996). It can be advantageous for athletes to learn how to tread water, possibly with the use of a floatation belt, while incorporating a running motion—and to use this exercise on recovery days as a form of prehabilitation. Most importantly, before ever attempting to hurdle, would-be steeplechasers should first acquire the requisite range of motion, flexibility, strength, coordination and balance through general conditioning work.

The steeplechaser's technique carries the torso closer to vertical than when clearing a barrier in the 110 meters hurdles. The angle of the athlete's head while hurdling a barrier can largely determine the angle of the torso and position of the center of gravity. Normally, it is best to keep your head up and your vision focused about 15 yards ahead on the track, and for the torso to recover to a more vertical position almost immediately after you clear a barrier. Like the hurdler, the steeplechaser should get the lead foot down on the track surface as quickly as possible, but then stay high on the lead foot by first making contact with the ball of the foot. The steeplechaser can then be characterized as a midfoot or forefoot striker when hurdling a barrier.

Steeplechasers require strong and nimble feet. They also need to be able to balance and maneuver well when up on the balls of their feet. Steeplechasers benefit from auxiliary exercises such as barefoot running, plyometric exercises, jumping rope, burpies, jumping jacks, trampoline work, and weight training exercises such as curls, military press, and the snatch while balancing on the balls of their feet. Climbing in a rock gym (using proper safety equipment) can also strengthen the hands and feet. It also requires the same focus and level of concentration as hurdling. Athletes can also greatly strengthen their feet by climbing ten stadium steps barefoot, carrying dumbbells or five-gallon buckets of water in each hand, then slowly stepping down backwards. Buckets are inexpensive and can be filled with more water as the athletes progress. And in the event they lose their balance, the water will spill but no damage will be done. Many are shocked at the difference between what athletes can do while wearing shoes, versus performing this exercise barefoot.

Lead Leg and Trail Leg Hurdling Drills

When teaching lead leg and trail leg drills over hurdles, it can help to practice over three to five hurdles spaced less than 10 to 12 feet apart. The athletes can then turn and repeat the desired drill by negotiating a second flight of hurdles set two lanes to the outside, facing in the opposite direction. They can use the open lane between two opposing hurdles to alternately practice these drills with either leg. To practice alternating lead legs, a flight of three to five hurdles can be set up to require four instead of three or five steps between them. When proficiency has been demonstrated with hurdles set at 30 inches, athletes can then move up to 36 inches. At this time, the athletes would be working off the left or right side, but not the entire hurdle.

When athletes begin running hurdle drills, attention should be given to optimizing their arm action. The lead hand should be turned thumb-side-up, and the elbow should drive vigorously backwards and flex to create a “window” for the trail leg to pass through. Nevertheless, the arm action is not so rapid or wide as that for specialists in the 110 meters hurdles event due to the much slower speeds associated with barrier clearance in the steeplechase.

Women’s Nylons

When first teaching hurdling to young or inexperienced athletes, there is an invaluable piece of equipment that every coach should have—namely, a half dozen women’s nylons. Take a pair of nylons and cut the leg portions off. Set up two flights of hurdles, leaving an open lane between them. Then, stretch and tie each of the nylons between two hurdles. Use the same knot that you start with when tying shoelaces—that is, before you form the loops. The nylons are resilient enough to take a moderate blow and remain in place, yet athletes will know when they have made contact. If athletes miss badly, the knot will slip and they will not trip. The nylons are almost indestructible, and it only takes a second to re-tie the free ends back into place. This “secret weapon” can save novice hurdlers many battered knees, shins, ankles, toes, and several spread eagle landings on the track. Novices will be able to experiment and get closer to the hurdles—that is, they can be more aggressive and progress more rapidly toward mastering sound technique. However, once athletes master good hurdle technique, abandon the nylons and assign a high penalty for hitting a barrier during practice.

Hurdling and The Ritual

When athletes are finally learning to negotiate a full hurdle, it can help to use only a single hurdle and to place another hurdle right alongside, facing the opposite direction. This is the practice of Coach Chick Hislop of Weber State University, who many consider to be the finest steeplechase coach in the United States. Hislop has helped many athletes, and the author is indebted to him for generously providing his own writings and constructive criticism to enhance this treatment of the steeplechase.

Given two adjacent hurdles facing opposite directions, the athletes can then focus on a single target, and the act of turning about requires them to make a conscious effort to re-focus on the next hurdle. If they negotiate a flight of hurdles, athletes might shift from a more cognitive mode to automatism. While automatism is advantageous if not required for the 110 meters hurdles, this is not so for steeplechase, since the athletes move more freely about the track and then assume random positions relative to the barriers. Accordingly, random practice is needed to develop the requisite set of skills. In this drill, athletes move down the track at varying distances to randomly change their approach and lead leg. When this drill is performed, the coach may wish to stand about 15 feet from the hurdles so that brief comments on technique can be given as the athletes wheel around. Hislop commonly has athletes take 100 hurdles in this manner, and refers to this training session as “the ritual.” Prior to a competition, after warming up, the athletes can then engage in the ritual and take about 20 hurdles. Since the penalty for hitting a barrier in competition can be catastrophic, it is prudent for athletes to assign themselves with a 100-hurdle penalty if they happen to hit a hurdle during training. However, there can also be times and circumstances when hitting a hurdle might signal the end of a training session (Hislop, 1984, and 1999).

Hitting a Barrier

The imagination does not really prepare athletes for the stark reality of what can happen when they hit a barrier. It does not move or deflect in the least, rather, it is like running into a brick wall. It is probably better for athletes to first experience hitting a barrier in training, rather than in competition. And if there is such a thing as a best time for this, it is probably after they have mastered conventional hurdles, but prior to hurdling over barriers. A steeplechase barrier can be set up on the infield grass and padded with an old wrestling mat or futon to reduce the risk of injury when athletes begin to hurdle the barriers. Pads can also be placed on the ground on either side of their line of approach and exit. If and when they do hit the barrier, the risk of injury will be low and they can then walk away with the benefit of a sobering lesson.

Sometimes athletes will develop a mental block, fixate on a barrier, or some other aspect of hurdling technique, thereby suffering both a break in concentration and movement. In this case, the coach can sit or kneel about 15 yards down the track and suggest that the athletes focus on the coach’s eyes as they clear the barrier or water jump hazard.

> ***If I plan to enter this particular young man in a steeplechase again, I owe it to his parents to make sure he knows how to fall without killing himself. I made him take swimming last year...***
>
> —Bill Bowerman, on why he made Kenny Moore take gymnastics

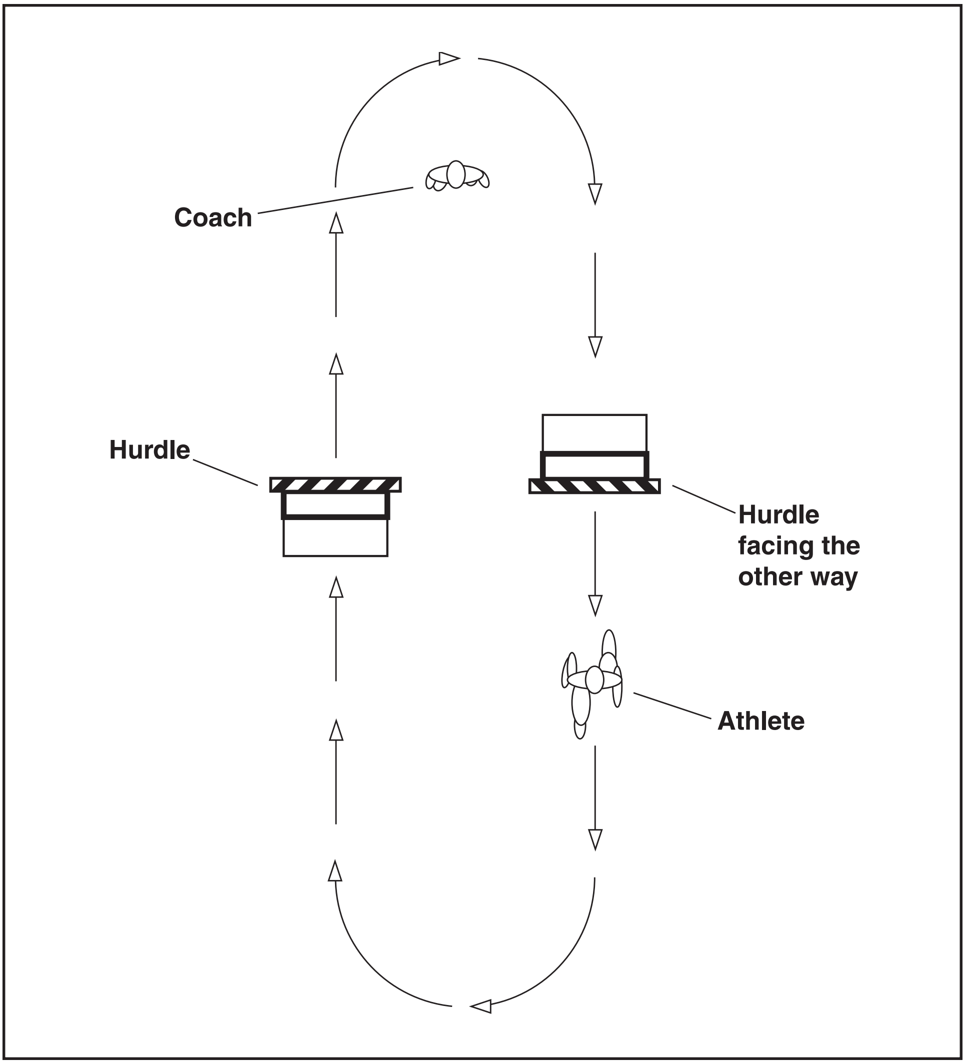

Figure 15.2—Top plan view, "the ritual"

Breathing and the Steeplechase

Steeplechasers need to be aware of their breathing, and should train their breath control. Often, steeplechasers inhale while leading with the knee and pause their breathing momentarily until their trail leg comes up. They then exhale forcefully, simultaneously thrusting the elbow of their lead arm back as they drive their lead foot towards the surface and descend over the hurdle or barrier. It is normal for a quick inhale to accompany actions that raise one's center of gravity. However, a markedly interrupted breathing technique is undesirable in the steeplechase. And generally, the slower and poorer the athletes' technique, the longer this breathing interruption will be. This can pose a problem, since steeplechasers need all the oxygen they can get to race well over 3,000 meters. For every fraction of a second that athletes interrupt their ventilation, they likely lose at least twice that

much time in the race. Steeplechasers need to learn how to breathe while bending forward from the waist, and can practice this from the sitting L7 position. It can also help for steeplechasers to practice some hypoxic training—that is, to occasionally run or swim a short distance while holding their breath. Puffing your cheeks and exhaling forcefully while coming off a barrier can also place some backpressure on the lungs and aid in oxygenation of the blood. With improved technique, the amount of time spent over the barriers will decrease and this will reduce disturbance to the breathing and running rhythm of the athletes. As a result, when the pace approaches 70 seconds/400 meters there is less of a performance difference between a two-mile run on the flat and the 3,000 meters steeplechase. In this regard, a performance differential of 20 seconds or less becomes possible.

Steeplechase Footwear

It is difficult to find suitable footwear for the steeplechase. For a number of years, Nike, Inc. has manufactured a limited quantity of track spikes exclusively for the steeplechase, but the availability of the product fluctuates. Often, only the top collegiate athletes and promotional athletes have been able to obtain a pair. Further, the extremely lightweight construction of the shoe does not lend itself to prolonged use. Often, only one or two races can be run in the shoes before they need to be retired. Few other shoe manufacturers have even considered making a specialty shoe for this event. Historically, Adidas, AG has produced fine specialty shoes for many sport activities, and a good product for the steeplechase called the “Adistar Steeplechase” is presently available.

In general terms, the steeplechase spike needs to be lightweight, even after being immersed in water. It requires ventilation means for shedding water. And it should elevate the heel by about a centimeter. It can help for the forefoot spike plate to be covered with a layer of synthetic rubber, or thermoplastic material with good adhesive properties *vis-á-vis* the wet and often painted surface of the water jump barrier. In order to better push off and extend over the water hazard, the forefoot area of the track spikes should be able to flatten, and even plantarflex, when athletes step and extend from the water jump barrier. Accordingly, it is sometimes advantageous to cut flex grooves into the forefoot area of the track spike plate so that it will be capable of articulating in the desired manner.

Warm-Up Routine

A proper warm-up routine for steeplechasers includes preliminary and light flexibility work to attain full range of motion in the major joints. This should be followed by a warm-up to break a sweat and attain a pulse rate of 120 bpm. Whenever possible, it is beneficial to warm-up and warm-down by running barefoot, but with hurdlers or steeplechasers this is almost an imperative. If grass is not available, a rubberized track surface can be preferable to not running barefoot at all. Barefoot running does a great deal to enhance proprioception and plantarflexion. After running barefoot, athletes experience a heightened aware-

ness regarding their feet and will be up on their toes instead of down on their heels. Whenever possible, they should complete their warm-up by running 10 x 100 meters diagonally across the infield, then jog a fast 50 meters to the opposite side in a continuous fashion. Athletes should then stretch in earnest and focus on the major muscle groups by conducting the following in sequence: static stretching, PNF, and then dynamic flexibility exercises, including the continuous Yoga-like routine presented in Chapter 7. Having accomplished this, steeplechasers will be ready for hurdle exercises such as “the ritual,” described previously.

Integrating Running and Technique Work

The 3,000-meter steeplechaser’s background conditioning and sharpening work generally corresponds to that of a 1,500-meter sided 5,000-meter runner. The conditioning requirements have been addressed in Chapters 1-6. During the base and hill periods, steeplechasers should practice their hurdle technique two or three times each week, whereas during the sharpening period they should actually be hurdling over obstacles once a week. Nevertheless, athletes should guard against conducting too much work over obstacles, since the associated shock loading can take a toll and result in injury. Accordingly, strive to integrate the required technique work with the general conditioning and sharpening work approximately three times a week in a sensible manner.

When working with novice steeplechasers, it is best to teach and practice new hurdle techniques when they are fresh. This would suggest doing technique work in a morning session, or prior to the primary afternoon training session. It can also help to conduct technique work on easy recovery days after the more demanding conditioning work performed the day before. However, once athletes have acquired the necessary technique, they also need to condition themselves to hurdling and taking barriers while in a state of fatigue, since that is what they will experience in actual competition. To do this, barriers can be placed next to an open lane, thus enabling the athletes to run on the flat or over obstacles during the sharpening workouts or time trials. In particular, when they are running distances longer than 400 meters, such as 800, 1,000, 1,200 or 1,600 meters, the athletes can then run alternating laps on the flat and over obstacles. In contrast with novice athletes, experienced steeplechasers can sometimes practice lead-leg and trail-leg drills, or hurdle obstacles after a demanding training session.

Determining Correct Split Times When Competing At Various Facilities

Track and field facilities differ in their geometry and positioning of the water jump, hence both the starting line position and the split times given can vary greatly. Coaches and athletes should then familiarize themselves with the projected split times for each particular track and field facility. Hislop calculates split times at various facilities by using the information provided in Table 15.1 (Hislop, 1984). For example, if an athlete wants to run 8:40 for the steeplechase at a facility with an outside water jump and the starting line is 50 meters from the finish line, then the calculations would appear as follows:

- 8:40 = 520 seconds = 1.73 seconds per 10 meters
- 5 X (1.73 seconds, from Table 15.1) = 8.65 seconds
- 520 seconds - 8.65 seconds = 511.35 seconds
- 511.35 seconds divided equally into 7 laps = 73 seconds/400 meters pace

In the case of a facility having an inside water jump and a starting line 230 meters from the finish line—then the calculations would appear as follows:

- 8:40 = 520 seconds = 1.73 seconds per 10 meters
- 23 X (1.73 seconds, from Table 15.1) = 39.8 seconds.
- 520 seconds - 39.8 seconds = 480.2 seconds.
- 480.2 seconds divided equally into 7 laps = 68.5 seconds/400 meters pace.

Racing

Athletes are wise to take the precaution of stepping the first barrier, since in the first lap the field is normally bunched-up and there can be a lot of jostling. In the abstract, there are only three good positions when running the first 2,400 meters of the steeplechase: in a lead group of no more than three or four athletes and positioned right off someone's shoulder, in lane two or three outside of the pack, or within striking distance behind the pack. If athletes are tangled up in the pack or boxed in along the rail, then they are simply in danger of hitting a barrier or crashing at the water jump. Prudent athletes will stay out of trouble because in the steeplechase that translates into hitting a barrier, or having a disaster at the water jump. Athletes with a superior fitness level can sometimes run clear of the field and avoid the problem. Other athletes can adopt the tactic of sitting behind the pack, and later make a deliberate move past the group to attain a favorable position. Sometimes an athlete can move from behind the pack and make a breakaway in the space of 100 meters.

Many athletes will greatly accelerate as they approach the barriers, since this facilitates hurdling. However, this common practice can also be a substitute for poor hurdling technique and inferior conditioning. And it is an expensive substitute, because these changes in pace represent an inefficient use of limited energy reserves. Better to have well conditioned specific muscle groups and a more efficient hurdling technique. Sometimes steeplechasers can make significant gains by improving the speed of their immediate attack and hurdling technique, rather than by accelerating greatly over the 15 meters preceding each obstacle.

Even pacing in the early laps of a steeplechase can be crucial to a successful performance. If athletes go out too fast, they can slow greatly in the middle or late portions of a race and this will make hurdling that much more difficult. In the steeplechase, there are enough disturbances of rhythm and pace due to hurdling the obstacles, and so the novice should not compound matters with uneven pacing. However, the race tactics of elite American athletes are sometimes far too predictable. In the United States, the steeplechase event has been dominated by a handful of individuals over the past 20 years. These athletes generally pace

8:00 = 480 seconds	=	1.60 seconds per 10 meters
8:05 = 485 seconds	=	1.61 seconds per 10 meters
8:10 = 490 seconds	=	1.63 seconds per 10 meters
8:15 = 495 seconds	=	1.65 seconds per 10 meters
8:20 = 500 seconds	=	1.66 seconds per 10 meters
8:25 = 505 seconds	=	1.68 seconds per 10 meters
8:30 = 510 seconds	=	1.70 seconds per 10 meters
8:35 = 515 seconds	=	1.71 seconds per 10 meters
8:40 = 520 seconds	=	1.73 seconds per 10 meters
8:45 = 525 seconds	=	1.75 seconds per 10 meters
8:50 = 530 seconds	=	1.76 seconds per 10 meters
8:55 = 535 seconds	=	1.78 seconds per 10 meters
9:00 = 540 seconds	=	1.80 seconds per 10 meters
9:05 = 545 seconds	=	1.81 seconds per 10 meters
9:10 = 550 seconds	=	1.83 seconds per 10 meters
9:15 = 555 seconds	=	1.85 seconds per 10 meters
9:20 = 560 seconds	=	1.86 seconds per 10 meters
9:25 = 565 seconds	=	1.88 seconds per 10 meters
9:30 = 570 seconds	=	1.90 seconds per 10 meters
9:35 = 575 seconds	=	1.91 seconds per 10 meters
9:40 = 580 seconds	=	1.93 seconds per 10 meters
9:45 = 585 seconds	=	1.95 seconds per 10 meters
9:50 = 590 seconds	=	1.97 seconds per 10 meters
9:55 = 595 seconds	=	1.98 seconds per 10 meters

TABLE 15.1—Times for the 3,000-Meter Steeplechase (Hislop, 1984, reproduced with permission)

themselves evenly and then attack with less than two laps remaining, or simply run away from the field. Not often do we see dramatic surging, or a hard breakaway attempt in the fourth or fifth lap, or even someone hurdling the water jump. Athletes need to be prepared for these tactics when competing in a field that includes the Kenyans.

The steeplechase is a highly technical event, but athletes should not over-intellectualize during competition. Rather, the goal is to become so proficient that the execution of proper technique will not interfere with the ability to concentrate and focus.

In possession of infallible technique, the individual places himself at the mercy of inspiration.

—Daisetz Suzuki

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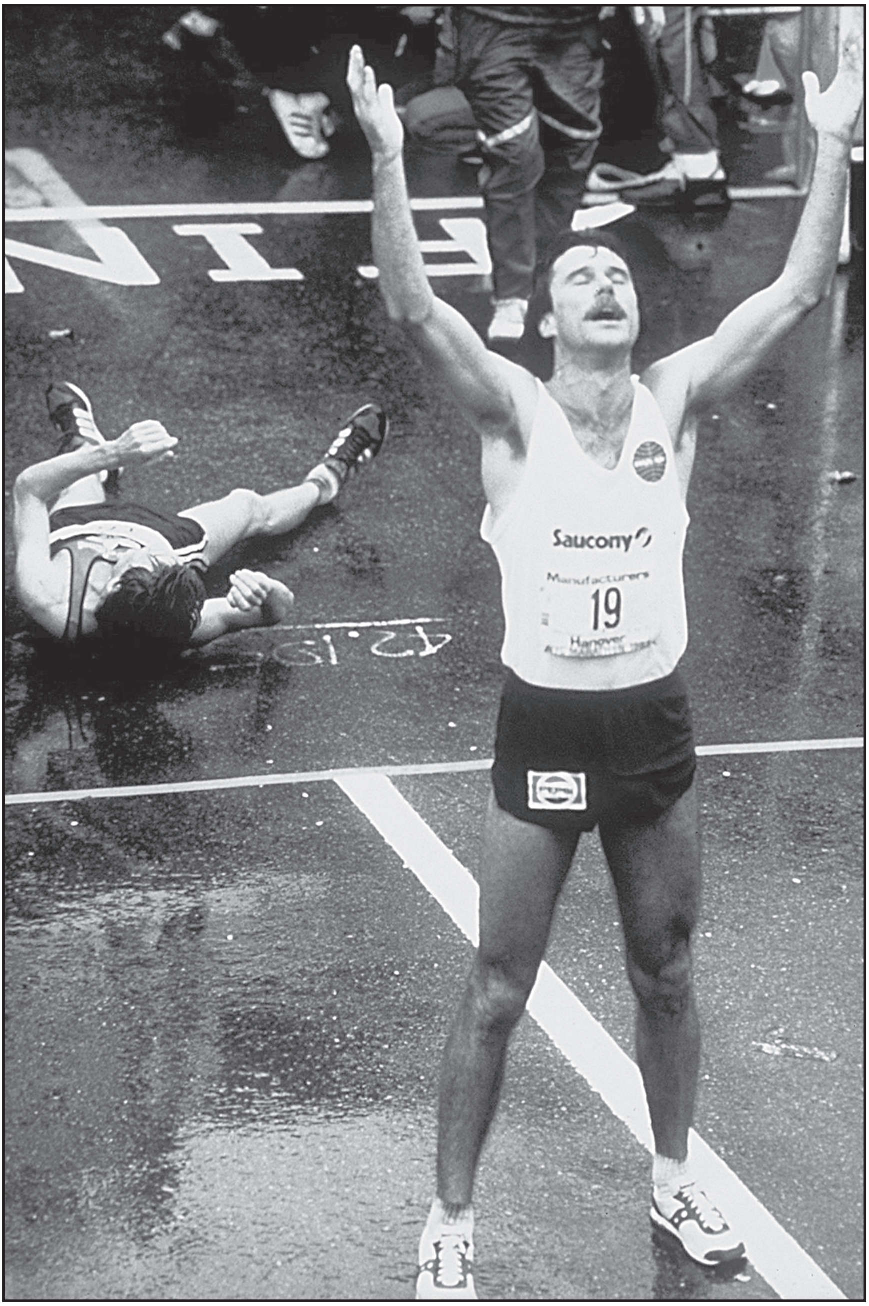

PHOTO 16.1—The agony and ecstasy of the marathon. Rod Dixon with arms outstretched in victory and Geoff Smith lying exhausted at the finish of the 1983 New York Marathon. Photo by Barbara Kinney. Copyright USA TODAY, 1983. Reprinted with permission.

CHAPTER 16

THE MARATHON

Legend has it that Pheidippides, the ancient Greek messenger who ran to Athens to announce the defeat of the Persians in the battle of Marathon, died after completing his mission. However, this is likely the “Hollywood” version of events, since he was actually one of the highly conditioned *hemerodromoi*, or intercity messengers of ancient Greece, and he had already covered a much longer distance of about 140 miles the previous day, in a vain attempt to solicit the help of the Spartans (Newsholme, Leech, Duester, 1994). In conjunction with the 1908 London Olympic games, the distance of the marathon event was fixed at 26 miles 365 yards, since that was the distance required to finish before the King and Queen’s booth. The marathon tends to conjure up images of dreaming the impossible dream and beating the unbeatable foe, but the truth is, there is nothing especially sacred or noble about this distance.

Recreational Runners and the Marathon

Thirty years ago, only a few hundred people would participate in marathon events, but today the contestants number in the tens of thousands. The question is whether this is truly a positive development with respect to the health and welfare of the participants? The author believes that it would have been better for today’s participants if the distance between Marathon and Athens had been half as long, and if the position of the Royal booth had cut the course even shorter. Why? For the answer, we need only to look at the effects of running the marathon on both elite athletes and recreational runners.

> ***Why couldn’t Pheidippides have died here?***
>
> —Frank Shorter, upon reaching the 16 mile mark in one of his first marathons

Elite Runner Marathon Casualties

Given the present national and world marks, an elite athlete will have to cover upwards of 100 miles per week in their training to be competitive at this distance. If you survey the top twenty marathon runners in the world, the average weekly mileage during the base period now exceeds 120 miles per week, and a few even cover over 160 miles per week—more mileage than some put on their cars. And in this country, most of the training will be conducted on asphalt roads and in athletic

shoes. The horse can cover such distances naturally and normally, but humans are configured to do so by walking rather than running. The amount of work that athletes must put forth to be competitive at this distance imposes chronic training over-loads. Many marathon athletes retire after suffering a debilitating injury or poor health, rather than because of the allure of more attractive prospects outside the sport. If one follows the history of elite marathon runners into retirement, there exist clear indications of premature arthritis and lingering soft tissue injury. In some cases, athletes who have over-trained suffer endocrine problems (Barron, Noakes, Levy, Smith, Millar, 1985).

Recreational Runner Marathon Casualties

Often the recreational runner assumes a considerable training over-load merely by attempting to complete the marathon distance. Some attempt as much in one day as they might normally cover in almost a week. It is not a sound training practice to increase the training load in a workout by over 10% in a single session. However, many recreational runners assume many times that by competing in a marathon. The results are predictable. Too many runners suffer injuries from dramatically increasing their training in preparation for this event, but also as the direct result of having completed a marathon. Unfortunately, individuals with relatively little training are sometimes encouraged to participate in a marathon, and numerous books exist which include advice for novice runners who wish to make the attempt.

The author wishes to de-bunk and deflate some of the current mystique surrounding the marathon, since he does not believe that it constitutes the best focus for recreational distance runners who are truly interested in cultivating their long-term physical and mental health. Of course, many distance runners want to run a marathon at least once in their lifetime, and for some individuals, once will be enough. In this case, the athlete will likely have three to five years of training background, and a solid foundation upon which to base an effort in the marathon. Even so, recreational and even elite distance runners generally should not compete in more than one or two marathons during a calendar year. And the vast majority of recreational distance runners are perhaps best advised to forego the marathon. Instead, it can be far healthier for them to focus their training and racing efforts on shorter distances in the range between the mile and 10,000 meters.

> ***To describe the agony of a marathon to someone who's never run it is like trying to explain color to someone who was born blind.***
>
> —Jerome Drayton

Down And Out For A Month

Following a full effort in the marathon, both elite and recreational runners are normally hobbled for several days. This is due in part to injury from shock loading and eccentric muscle contractions, but also the consumption of muscle protein

during the event (Janssen, 1987). A great deal depends upon how well athletes prepare for the marathon, and how they subsequently manage their recovery. It generally takes about a month for individuals to feel they have recovered. This puts the activity into proper perspective—ask yourself what other trauma or physical activities require such an extended recovery period. Many broken bones mend in five to six weeks, and following a blood donation, an individual's blood profile restores to normal in approximately the same amount of time. Accordingly, you might do well to weigh the decision to run a marathon at full effort as you would an injury or a minor surgery that requires at least a month of recuperation.

The Marathon As Mental Therapy

So why do it? The main character in the film *Forest Gump* started running across the continent because he suffered a broken heart. Perhaps the historical inspiration for this character was Arthur Newton, who started running long distances after his wife left their African plantation. He subsequently traversed nearly every continent, but with the exception of Antarctica. It might have been a lot easier to find another woman. Running is sometimes a physical manifestation of psychological denial—a way to run away from something. And it can lend itself to obsessive and compulsive behavior. Preparing for and running a marathon seldom provides a viable solution for an individual's personal and emotional problems. It is far better to face those problems directly, and constructively address the demons that sometimes arise. Life is short. Do not take the path of Forest Gump, or similarly, spend several years following telephone poles and train tracks like the character Travis in the film *Paris Texas*. As clinical psychologist Dr. Scott Pengelly sometimes says to athletes or patients: "De-nial... is not the name of a river in Egypt" (Pengelly, 1988-1997).

Sometimes uttering the phrase, "I'm doing a marathon," is a cry for attention. It can be a plea for help from an individual suffering from low self-esteem, who is seeking external remedy and support via kind words, love, and peer group acceptance. However, the remedy for low self-esteem does not lie in externals, but rather, in an internal process of self-cultivation. If you really want to develop internal power and self-respect, then run the marathon distance alone in practice, take a long drink of water, and don't say a word about it to anyone.

Distance running can be a form of moving meditation, but it's not a religion, nor is it a unique, mystical, transcendental experience. Indeed, it can have mystical and transcendental moments, but no more so than any other activity in which an individual cultivates excellence. Activities such as writing a novel, or volunteering to help others in need, normally exceed the social value of running a marathon. Accordingly, it is good to keep these things in perspective.

The Mile Versus The Marathon

If you are a recreational distance runner and concerned with cultivating long-term physical and mental health, then you would be best advised to train and compete at shorter distances in the range between the mile and 10,000 meters. It is possible to prepare for these events by training as little as 20 to 40 miles per week, thus greatly reduce the risk of suffering an over-use injury. This is a more

manageable training load for individuals of any age, particularly when the recreational athlete has other more important priorities and responsibilities in life. Further, an event like the mile requires a balance of aerobic and anaerobic abilities, and is a healthier distance both for which to train and compete. It is also a truer test of an athlete's overall fitness and running ability. That is why the 1,500 meters and mile remains the glamour event of track and field.

Training for the mile or 5,000 meters also makes more sense from the standpoint of how our bodies age. As we become older, our metabolism tends to shift from anabolism towards catabolism. For example, a man does not normally have as much testosterone going at age 45 as he did at 20. So to maintain health and fitness, it is generally advisable to place a greater emphasis on strength training as we age. It is now widely accepted that the elderly can often benefit greatly from a sensible strength-training program, and in part, due to the youthful response thereby solicited from the endocrine system (Campbell, Crim, Young, and Evans, 1994). Preparing for and competing in longer events (15 kilometers to the marathon) tends to render an individual's metabolism more catabolic, and that is not what most middle-aged or elderly people having a normal body weight really want or need in order to enhance their general health (Kuoppasalmi, et al., 1980, Tanaka, et al., 1986, Bonen, et al, 1987, Hackney, et al., 1988, Arce, et al., 1993, Jensen, et al., 1995, Urhausen, et al., 1995).

So You Still Want to Run a Marathon?

If you are a recreational distance runner with positive physical and mental reasons for running a marathon, then you might consider the following advice: Run the event at only 1/4 or 1/2-effort, and do not attempt to run any harder. If the difference between a full effort and a 1/2-effort is a marathon run in 2:36 versus 2:48, or 3:00 versus 3:18, what does the time really matter? If you finish still feeling relatively well in 3:18 when you can actually run about 3:00, are you a lesser individual by 18 minutes? One thing is certain, at 1/2-effort you will normally feel recovered within a few days or a week, but if you race full out, a month later you might still be feeling injured and exhausted. Start the marathon running easily, and slower than your approximate target pace. If you have need to travel to find a marathon event, then pick one with pleasant weather and a beautiful course. Stop and smell the roses along the way. If near the ocean, perhaps attempt to go surfing afterwards. Make the experience a small part of your larger vacation plans. People sometimes make the process of preparing and competing in a marathon the center of their lives, and behave as though it were the quest for the Holy Grail. In truth, the marathon is three hours of your life, more or less, on a Saturday or Sunday morning.

> ***If you feel bad at 10 miles, you're in trouble. If you feel bad at 20 miles you're normal. If you don't feel bad at 26 miles, you're abnormal.***
>
> —Rob de Castella

A Marathon Training Schedule for Recreational Distance Runners

Let's say you are training about 40 miles per week and cultivating your fitness for the mile and 5,000 meters, but then decide you want to run a marathon. How should you train for it? In brief, you should hardly change anything at all. Simply, gradually extend the duration of the easy long run you normally undertake on the weekend. If 60 to 80 minutes has been the habit, then slowly build up to 90, and then to 100 minutes. On the last weekend of a given training meso-cycle in the base and hill periods, attempt to run for a full 110 to 120 minutes, but not beyond 120 minutes unless the spirit moves you. And during this run, do not be afraid to stop for a drink of water, a bathroom break, or to view the scenery. During the course of the athletic season, race anywhere between 1,500 meters to 15 kilometers in the usual manner by placing competitions at the end of a worthwhile break. Plan to race a distance no longer than 8,000 meters or five miles, somewhere between 10 to 14 days prior to the marathon event. Recover from this race over the next four to six days, then time trial—that is, run a distance between 1,500 and 3,000 meters at 3/4-effort on the fifth or sixth day before the Marathon. Recover over the next two or three days and then run a few relaxed stride-outs at 200 meters, no faster than 1,500 meters goal pace, on the third day before the marathon.

Given this approach, if you are fit enough to run a five-minute mile while only covering 40 miles per week, you will likely be far better off on race day than someone else who can only turn a mile in 5:30 as the result of so-called "marathon training." On race day, remember not to run the marathon at greater than 1/2-effort. An abstract schedule which could be suitable for a distance runner for the last 14 days preceding the marathon is provided:

14 Race 8,000 meters
13 Active Recovery
12 Easy Effort, Long Run, but not longer than 100 minutes.
11 Passive Recovery
10 1/2-Effort, Fartlek + 2-3(4 x 200m) at 1,500m goal pace
9 Active Recovery
8 Easy Effort, Long Run, but not longer than 80 minutes
7 Passive Recovery
6 3/4-Effort, Time Trial 1,500m-3,000m, or conduct the same distance in the uneven pace manner of the 30-40 drill
5 Active Recovery
4 Finishing Speed 6-8 x 200m at 1,500m goal pace
3 Active Recovery
2 Easy Recovery
1 Day Before Race Routine
0 Marathon

Ultras and Ironman Triathlon Events

Some individuals might wonder about participating in "Ultra" events such as 50-mile, 100-mile, or Ironman Triathlon events. From a long-term perspective, the benefit of these activities for athletes is questionable, since severe trials of this kind can threaten their subsequent motivation, fitness, and health. If you want to participate in ultra events, make sure your reasons for doing so are positive. The body with which you have been blessed is the only one that you will ever have.

Advice for Elite Distance Runners Attempting the Marathon

What about the elite athlete who desires to compete in the marathon? Appendix I provides an example of a marathon schedule for an elite athlete. However, it is important to address a number of common questions and mistakes regarding marathon preparation.

Perhaps the first great mistake for an elite athlete is to "become a marathoner," since to many this unfortunately means:

- Running high mileage in excess of 120 miles per week
- Conducting frequent interval or repetition workouts at marathon goal pace, such as sessions covering 15 kilometers including repetitions between one and five miles in distance
- Running predominantly road races and distances exceeding 8,000 meters

Within a year or two of engaging in this type of training most would-be marathoners have been reduced to economical shufflers. Their performances at 1,500 meters, 5,000 meters and 10,000 meters can regress significantly. In truth, they have lost some of the tools necessary to succeed at the highest level, even in the marathon event.

Elite athletes who desire to succeed in the marathon should only compete in this event once a year. Other than the possible need to qualify for a major international competition, there is only one reason for elite athletes to compete in more than one marathon a year—money. And if athletes are not in great need of money, the reason can sometimes be traced to vanity. Greed is the great killer of athletic careers.

If elite athletes desire to preserve the longevity of their careers and ability to perform in the marathon, they need to maintain their ability to compete on the track at the national and international levels in the 5,000 and 10,000 meters. For this reason, they should occasionally compete in off-distances, such as 1,500 and 3,000 meters, during the track season. One of the two athletic seasons conducted each year should then be directed towards the track, and the other to the marathon. This strikes a healthy balance and can permit improvement during both seasons. Training for the marathon then becomes preparation for the track season, and vice-versa.

For example, when Emil Zatopek won the marathon in the 1952 Olympic Games, it was after first winning the 5,000 and 10,000 meters. That was before

the Olympic Games grew to such an extent that the 5,000 and 10,000 meters required numerous qualifying rounds. Frank Shorter and Kenny Moore placed first and fourth in the 1972 Olympic Marathon, and to date, this remains the best finish by the United States. At that time, both men were fit to run quality performances at 5,000 and 10,000 meters. Moore recalls running 13:44 for 5,000 meters in Scandinavia prior to the marathon, and being disqualified after having been shoved off the track by Jos Hermans and forced to make a detour through the long jump pit (Moore, 1999). In the 1972 Olympic Games, Frank Shorter placed fifth in the 10,000 meters final, and then eight days later won the Gold Medal in the marathon. In 1976, Shorter had won the 10,000 meters event in the Olympic Trials, but did not risk running the event in the Olympic Games, since he had developed a stress fracture in his foot. He then placed second in the Olympic marathon behind Valdemar Cierpinski (Shorter, 1999). Lasse Viren still managed to place fifth in the 1976 Olympic marathon after weathering numerous preliminary rounds en route to winning the 5,000 and 10,000 meters. Carlos Lopes ran 27:17.48 behind Fernando Mamede's 10,000 meters world record of 27:13.81 on July 2, then won the marathon in a time of 2:09.21 on August 12 in the 1984 Olympic Games. This makes the point that athletes should not move up to the marathon simply because their marks at 5,000 or 10,000 meters are not what they would like. In truth, if athletes cannot perform well in these events, they are not going to be competitive in the marathon against national or world-class performers. In this regard, recognize that an athlete who can run 10,000 meters at 4:30 per mile pace is likely to be just as efficient as one who can only run 10,000 meters at 4:45 per mile pace. When they meet and race in the range of 4:50 to 5:00-mile pace in the marathon, and the former athlete increases the pace to 4:40 at the 22-mile mark or makes a break with less than a kilometer to go, the outcome will normally be determined in his favor.

Accordingly, during the base and hill periods elite marathon runners should conduct the 3/4-effort anaerobic threshold and steady state training sessions between 10,000 meters and marathon goal pace. To maintain a high level of efficiency and running economy, they should once a week conduct an interval session consisting of something like 4 (4 x 200m), or 3 (4 x 300m) at 1,500 meters date pace, or 3-4 (4 x 400m) at 3,000 meters date pace. The quality of this session will then improve to goal pace during the sharpening period. This interval session can also serve to counteract the tendency of high mileage work to shift the blood pH too far towards the base side, particularly when athletes are training at altitude. During the sharpening period, athletes should essentially train as if preparing to compete in the 10,000 meters, except that they will need a longer than normal long run and higher overall mileage. Marathon runners need to be conditioned to run in excess of two hours. For this reason elite marathon runners should conduct a long run once every seven to 10 days. The maximum duration of the long run should gradually increase from two hours to over three hours by the end of the base and hill periods. In this regard, do not increase the duration of the long run every seven to 10 days, but rather only once every second or third week.

However, elite athletes should reduce the duration of the long run to less than or equal to two hours during the sharpening period, and then to less than 1:40 minutes during their taper or ascent to peak performance.

The Carbohydrate / Fatty Acid Threshold

To be successful in the marathon and even longer distances, athletes need to be able to efficiently use fatty acids as an energy source. At one time, many thought that carbohydrates were used almost exclusively for the first 90 minutes of the marathon, and when they were depleted, the runner would “hit the wall” and start using fatty acids as the primary energy source. What actually happens is a bit more complicated. When athletes are at rest or engaged in light exercise such as walking or easy running, most of their energy comes from fatty acids, particularly those in their blood plasma, and also their intramuscular triglycerides. In contrast to the adipose tissue you might find in the area of your “love handles” or thighs, which is essentially a useless form of fat unless you are facing starvation, the intramuscular triglycerides are stored in your muscle tissue. And a relatively small amount of fatty acids can provide a lot of energy—in particular, 35 kJ/ gram, as opposed to only 16 kJ/ gram for carbohydrates (Newsholme, Leech, and Duester, 1994). Think of the fatty acids as diesel fuel. It is not the best substrate for high-speed performance, but you can run economically for a long time while burning fatty acids. Aerobic lipolytic metabolism, or simply “fat metabolism,” requires oxygen, whereas carbohydrates can be used both with oxygen (aerobic glycolysis) and without oxygen (anaerobic glycolysis) (Hawley, 1995). The energy demand of untrained athletes can largely be met by using fatty acids until they approach approximately 35% of their VO_2 maximum, but highly trained athletes can continue to use this substrate when performing at up to 65 to 70% of their VO_2 maximum (Hurley, 1986, Janssen, 1987, Sleamaker, 1989, Coyle, 1995, 1997).

Obviously, it is important for marathon runners to enhance their ability to use fat metabolism. The simple answer is quantity. Athletes need to assume relatively high mileage and distance runs having a long duration. This stimulates the creation of numerous mitochondria, capillaries, and large stores of intramuscular triglycerides. Figure 2.7 illustrates this training adaptation, and for convenience it is reproduced in this chapter as Figure 16.1.

Figure 16.1 suggests that fatty acid substrate use can be elevated to supply a substantial portion of the energy needed when functioning at 80% of VO_2 maximum. This may be pushing it with respect to distance runners, but the point is that an athlete’s relative use of fatty acids as a substrate during exercise can be trained. As the body’s total carbohydrate stores can only provide for about 90 minutes work in the marathon, greater relative use of fatty acids early on can spare the limited carbohydrate stores for later use. This can also help prevent or delay the more dramatic shift towards the use of fatty acids, commonly known as “hitting the wall,” in the later stages of the marathon.

However, when athletes exercise at a rate or intensity that exceeds the ability of fat metabolism to provide the required energy, then carbohydrates must be

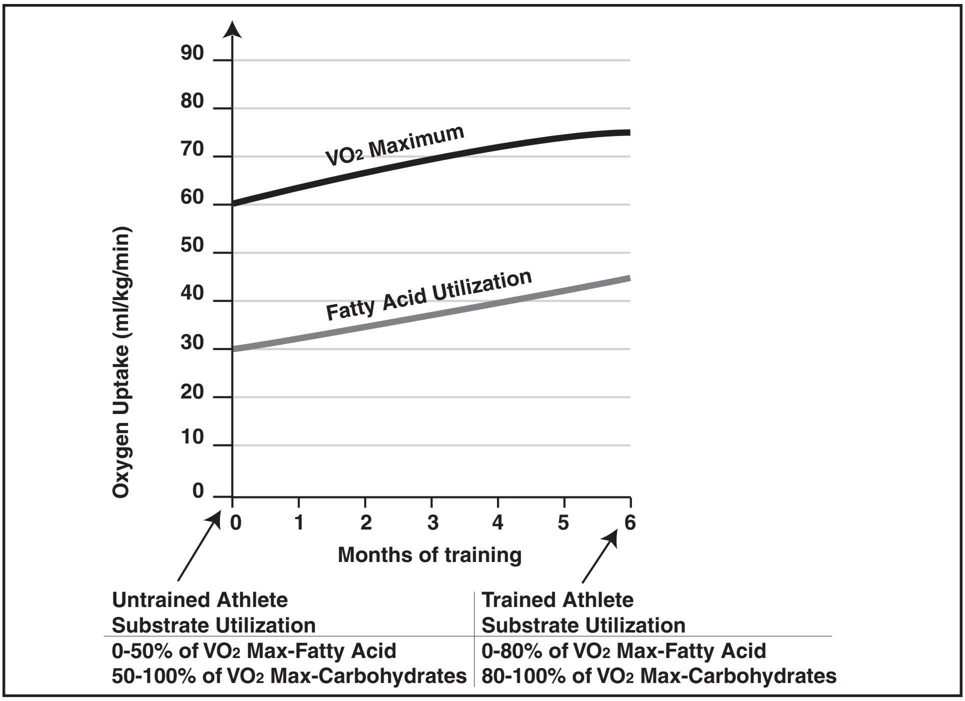

FIGURE 16.1—from Janssen, 1987

used to meet the energy demand. The primary limitation of fat metabolism is that it can only provide energy half as fast as aerobic glycolysis using carbohydrates. Further, the intramuscular triglycerides burn rather like diesel fuel, whereas carbohydrates burn like high-octane premium and provide more power. The process of aerobic glycolysis (i.e., burning carbohydrates in the presence of oxygen) produces twice the amount of ATP per unit time and 11% more energy than triglycerides (Newsholme and Leech, 1983, Janssen, 1987, Newsholme, Leech, and Duester, 1994, Coyle, 1995, 1997, and Autio, 2000). These carbohydrates are present in the form of blood glucose and are stored in the form of muscle glycogen and hepatic (liver) glycogen. When running a marathon, the approximate total energy that can be derived from *blood* glucose provides for 4 minutes, *muscle* glycogen 71 minutes, and *hepatic* glycogen 18 minutes of exercise (Newsholme and Leech, 1983). Some portion of fatty acids must then be used to cover the marathon distance. In truth, fatty acids and carbohydrates are both being used from the start of the marathon. But somewhere in the range between 35 to 70% of VO_2 maximum, the relative ratio of consumption shifts more dramatically towards carbohydrates whenever athletes exceed their carbohydrate/fatty-acid threshold (Sahlin, 1986, and, Brooks et al, 1994).

The point at which this transition takes place can be identified by both the respiratory quotient (RQ) and the onset of lactic acid accumulation. An RQ of .707 indicates that 100% of fatty acids are being used as substrates, whereas an RQ of 1.0 indicates that 100% of carbohydrates are being used as substrates. The point at which the total energy contribution comes equally from carbohydrates

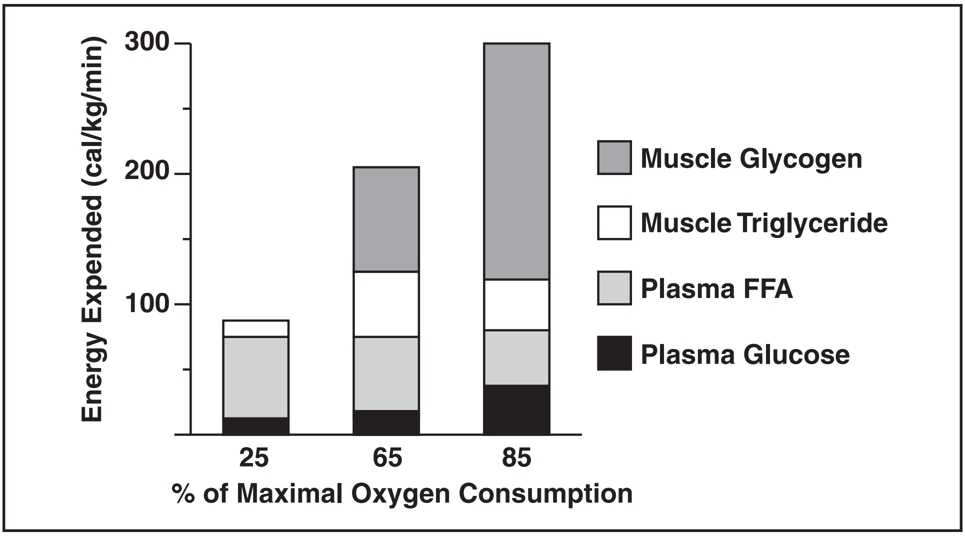

FIGURE 16.2—from Coyle, 1995

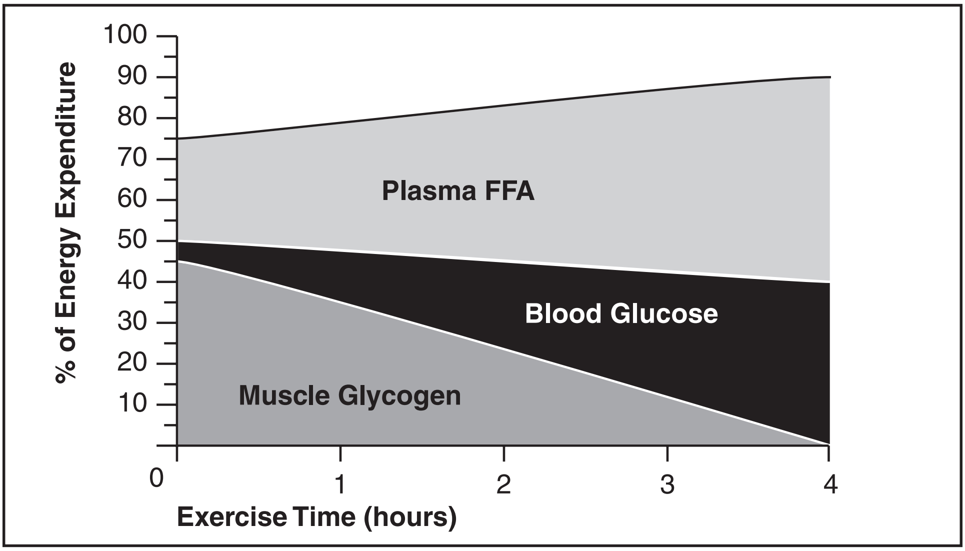

FIGURE 16.3—from Coyle, 1995

and fatty acids corresponds to a RQ of .85 (Brooks et al., 1994). One researcher investigated the relative amount of carbohydrates and fatty acids used when the amount of oxygen made available to runners was changed. The athletes exercised at 65% of VO_2 maximum and were provided with air containing 14%, 21%, and 30% oxygen. As a point of reference, air normally consists of about 21% oxygen at sea level. Given only 14% oxygen, the RQ was .965 and only 11.2% fatty acids were used. Given 21% oxygen, the RQ was .889 and 35.8% fatty acids were used. And given 30% oxygen, the RQ was .874 and 41.2% fatty acids were used (Linnarsson, 1974). The more oxygen that is available, the more that fatty acids can be used. Accordingly, when athletes are not acclimatized to altitude, or when they face hot and humid conditions, they will metabolize more

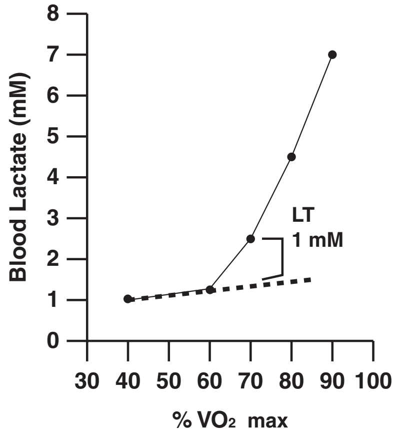

FIGURE 16.4—From Coyle, 1995

carbohydrates. Another researcher, studied the relative use of fatty acids when athletes exercised at various percentages of their VO_2 maximum. Fatty acids were found to provide 60% of the energy at 20% of VO_2 maximum, 53% of the energy at 50% of VO_2 maximum, 36% of the energy at 70% of VO_2 maximum, and three to 13% of the energy at 85 to 90% of VO_2 maximum (Pruett, 1970).

Figure 16.2 shows the relative use of fatty acids in the form of intramuscular triglycerides and plasma free fatty acids, and also that of carbohydrates in the form of muscle glycogen and plasma glucose, at various levels of exercise intensity. Figure 16.3 shows the percentage of energy produced by various substrates over time when exercising at 65 to 75% of VO_2 maximum.

Figures 16.2 and 16.3 are especially relevant to this discussion since it has been found that lactate accumulation typically begins in marathoners at about 70% of VO_2 maximum—and they maintain approximately 75% of VO_2 maximum during the event (Costill and Fox, 1969, Costill et al., 1973, Coyle, 1995). Coyle defines the lactate threshold as the intensity of exercise at which blood lactate concentration is 1mM above baseline (Coyle, 1995). Figure 16.4, adapted from Coyle, depicts a typical blood lactate accumulation curve for trained runners working at various percentages of their VO_2 maximum.

The blood lactate level in an individual at rest is normally approximately 1.0 mM. As indicated in Figure 16.4, the lactate threshold is at about 70% of VO_2 maximum and a blood lactate of 2.5 mM. This value may correspond with the carbohydrate/fatty-acid threshold of a highly trained athlete, which is different and lower than the anaerobic threshold corresponding to the heart-rate deflection point. The onset of lactate accumulation provides a concrete reference point for when the metabolism begins to shift from the use of fatty acids to carbohydrates, since fat metabolism is not associated with the production of blood lactate. The rate of blood lactate accumulation can vary considerably from one person to another, and also in the same individual, depending upon the nature of their training program and fitness level. Hence, there is nothing determinate about the particular lactate curve shown in Figure 16.4. Jack Daniels has found that well

trained athletes consistently work at approximately 86 to 88% of their VO_2 maximum when conducting a one-hour steady state run (Daniels, 1999). This concrete result can then be used as a benchmark to assess and predict an athlete's performance potential at various distances. Moreover, this level of intensity closely corresponds to the anaerobic threshold and heart-rate deflection point of well-trained athletes. The blood lactate value associated with the anaerobic threshold most often seen in the literature is 4 mM. However, the actual blood lactate levels exhibited by distance runners commonly varies between 4 and 8 mM during a one hour steady state run (Daniels, 1999, Coyle, 1999, Costill, 1999).

Athletes can raise their carbohydrate/fatty-acid threshold by adopting a training protocol analogous to how the anaerobic threshold can be raised. But neither the anaerobic threshold steady state nor the evenly paced steady-state runs emphasized during the base and hill periods best accomplish this task. Both of these training activities have high intensities and require the predominant use of carbohydrates as fuel. Instead, the long run achieves this result. However, rather than conducting an easy long run at less than or equal to 1/4-effort, the competitive marathon runner should perform the long run at 1/2-effort, or slighter better—that is, between approximately 60 to 70% of their VO_2 maximum, right along the carbohydrate/fatty-acid threshold. By the end of the base and hill periods, the elite marathon athlete running at sea level does not then conduct the long run at 6:30 to 7:00 minutes pace, but rather at 6:00 minutes pace or even better, and for a duration in the range between two to three-and-a-half hours.

Kenny Moore, the fourth place finisher in the 1972 Olympic Marathon, confided that he built himself up to such a degree that he eventually covered 38 miles at 6:00 minute pace in his long run. Moore felt he needed to conduct an extremely long run to compensate for the fact that he did not and could not regularly exceed 90 miles a week in his training and remain injury free, whereas he knew that Frank Shorter would sometimes log 140 miles per week in preparation for the marathon (Moore, 1999). Shorter's long run lasted two hours and he ran it on paved roads. He would begin at about 6:00 minute pace, but then would increase the pace over the second half of the training session according to how well he felt (Shorter, 1999). However, you must also appreciate and factor in that this training session was sometimes being conducted on demanding terrain and at an altitude between 5,400 and 8,000 feet in Boulder, Colorado.

Therefore, the long run conducted at 1/2-effort, or slightly better, can be regarded as an essential ingredient for marathon success. Nevertheless, exercise physiologists do not fully understand how the body becomes more efficient at using fatty acids, or why otherwise comparable individuals exhibit such different blood lactate responses during exercise. However, a number of things provide us with some clues. Elite athletes with similar VO_2 maximums and anaerobic thresholds do not always have the same level of success at the marathon as they do at 5,000 and 10,000 meters. All other things being equal, the 80-to-90-mile per week athlete is not competitive with the 100-to-120-mile per week athlete when

they line up in the marathon. And the latter tends to have difficulty competing with the 120-to-140-mile per week athlete. Generally, the talented 80-to-90-mile per week athlete will be a 2:14 to 2:20 marathoner, the 100-to-120-mile per week athlete a 2:10 to 2:12 marathoner, and the athlete running 120 to 140 miles per week a sub 2:10 marathoner. When training for the marathon, more than in any other running event, quantity does matter.

Elite athletes with many years of training might be able to slightly elevate their VO_2 maximum, anaerobic threshold, stroke volume, and both their muscle mitochondria and capillary density by taking on higher mileage and a long run lasting between two to three-and-a-half hours. However, the author does not believe that most of their subsequent improvement can be traced to these variables. Another possibility is optimization with respect to muscle fiber type, in particular, the Type I and Type IIc muscle fibers, and their related aerobic enzyme activity. Nevertheless, probably the greatest single variable influenced by taking on higher mileage and the two-to-three-and-a-half-hour run is running economy. To run 120 miles per week on a regular basis, athletes have to become extremely efficient, otherwise they soon beat themselves up and become injured. Frank Shorter had a VO_2 maximum of 71.3 ml/kg/min and Derek Clayton, a VO_2 maximum of 69.7 ml/kg/min, which are not especially high values for elite athletes, but both men had excellent running economy.

So far, this discussion of running economy has focused an athlete's gross mechanical efficiency. However, a more subtle aspect of running economy concerns an athlete's technique and application of force. It has been found with cyclists that athletes with a higher anaerobic threshold sometimes accomplish this task by distributing the power output over greater muscle mass (Coyle, 1995). This lowers the intensity of local muscle contractions, and can thereby result in less occlusion of blood supply. Further, this allows specific muscle fibers to be less frequently activated, permitting them more recovery time. And this probably also means they can use a greater proportion of fatty acids as a substrate and spare the use of carbohydrates while the athlete functions at a higher percentage of VO_2 maximum. This is important in helping to maintain elevated blood glucose levels in the latter stages of a marathon, thus avoid central fatigue and the dramatic shift towards using fatty acids that results in athletes "hitting the wall." It is also important for clearing blood lactate, which is produced when carbohydrates are being used as the primary substrate. Recognize that blood lactate and VO_2 maximum tests are gross indicators with respect to input and output, but they do not really tell us much about the actual use of oxygen and production of lactate within specific muscle groups.

Geoff Hollister at Nike, Inc. once commented that he had observed the wear pattern of Frank Shorter's shoes and remarked that Shorter used his entire foot—that is, he distributed the load and forces over a large surface area. Shorter estimates that he probably did about half of his training on natural surfaces, and he alternated periods of training at altitude in Boulder, Colorado with brief stays at sea level (Shorter, 1999). His running technique also stands out in the minds of

many observers as both economic and graceful. The great Australian distance runners of the 1950's and 1960's conducted a significant portion of their training on natural surfaces, as do the African runners whenever training in their home country. Certainly, the amount of hip extension exhibited by the African runners is not found in athletes who do most of their running on asphalt. Further, when athletes run on natural terrain there is a constant, subtle variation and improvisation of their footplant, stride, arm carriage, hand gestures, and overall running technique. Their running tempo dictates the primary rhythm or melody, and to borrow two other words from the realm of music, they also have *Rubato* or *Descant*. As opposed to being robotic, the movements of these athletes appear relaxed, fluid, and artistic, as in dance. The introduction of spontaneous subtle variations and improvisations in running movements distributes the workload over more muscle mass. Unfortunately, this aspect of running economy is often overlooked. Emil Zatopek, the 1952 Olympic Champion at 5,000 meters, 10,000 meters and the marathon, was known for spontaneous variations in his running technique and facial expressions. When cornered by a reporter and asked about his unaesthetic technique, he simply replied that running was not like ice skating—it was not necessary to smile and please the judges, it was only necessary to run fast (Mader, 1979).

The Australian coach Percy Cerutty well understood this phenomenon, as evinced in the following excerpts (Cerutty, 1961):

> ***Everything pulses in Nature; there is ebb and flow, a wave system is found in all or most things; nothing is static; nothing fixed or permanent; nothing without oscillation of some kind, yet athletes run as if their energy poured out in a steady stream... Running is movement, but variety in those movements is the essence of it...***
>
> ***These cyclic wave motions are not necessarily very obvious, but the athlete must have them: must be conscious of them: able to vary and use them at will.***
>
> ***Even the forward progression should be in a series of moving waves or cycle beats. Not necessarily obvious, but there, all the same. Everything in Nature conforms to a pulse or rhythm, to wave motions, surges and rest periods. The athlete must seek the means to use these things, to feel them in his own experience, if he would achieve the ends that lead to superlative performance.***
>
> —Percy Cerutty

Depletion of Muscle Glycogen during sustained exercise

Duration of exercise (min.)	Content of glycogen (μmol.g^{-1} fresh muscle)† Untrained	Trained
0	94	100
20	39	55
40	22	39
60	11	14
80	0.6 (exhaustion)	11
90	—	0.16 (exhaustion)

*Data from Hermansen et al. (1967)
†Glycogen measured in quadriceps muscle after removal of biopsy sample

TABLE 16.1—from Newsholme, 1983

Some might interpret Cerutty's remarks as poetic, but the case can be made that he accurately described aspects of running economy and performance that have not yet received enough attention by exercise physiologists. Now with the advent of portable VO_2 maximum and lactate equipment, researchers might consider getting out into the field and observing what takes place when running on asphalt, grass, woodchips, and barefoot along the beach and over sand dunes. There may be something worthwhile to be learned from such field experiments.

Central Versus Peripheral Fatigue

Part of the phenomenon of "hitting the wall" has to do with the brain's reaction to the lowering of blood sugar and diminished reserves of carbohydrates. The brain can only use carbohydrates as a source of fuel. When blood sugar levels drop beyond a certain point, signaling that carbohydrate stores are approaching total depletion, the brain suddenly steps in as if to say: "Sorry muscles, but I have to save the rest here for me. You will have to burn mostly fatty acids and some proteins now." It is a matter of the central nervous system protecting itself, in contrast to peripheral fatigue. As shown in Table 16.1, a trained athlete can deplete muscle glycogen levels to a significantly lower level than an untrained individual before reaching exhaustion.

However, it does not appear that well trained athletes can actually change their characteristic concentration of blood glucose that triggers central fatigue. There are differences between individuals, but a highly trained an individual's central fatigue "magic number" for low blood glucose remains substantially the same over many years. Edward F. Coyle stated that he tested one subject over a period of 15 years in various states of fitness. Whenever the individual would hit a low glucose level of 2.5 mM, central fatigue would set in and the individual could

invariably tell him when it happened (Coyle, 1999). Note that hypoglycemia can cause temporary mental impairment, loss of consciousness and coma, so do not take it lightly.

Low blood glucose is not the only contributor to central fatigue. The action of a number of neurotransmitters is also involved. Of the 20 amino acids, three branched-chain amino acids are oxidized in muscle as opposed to the liver. If the concentration of branched-chain amino acids in the blood decreases, then more tryptophan will enter the brain and cause more 5-HT (5-hydroxytryptamine, a neurotransmitter) to be produced. This substance acts as a depressant, inducing feelings of fatigue, decreased aggressiveness, and drowsiness (Newsholme, Leech and Duester, 1994).

Humans and other predatory animals tend to protect brain function by shutting down mechanical function so as to maintain blood glucose levels and sufficient carbohydrate stores. Some animals that rely solely on flight as a survival mechanism may not have the same safeguards or biochemical inhibitions. A horse or an antelope either outruns the bear or cheetah or it dies. These animals are then capable of literally running themselves to death. However, humans have survived in their struggle against other predators with the use of superior intelligence.

Altitude Training Is Essential

Elite athletes will also need to train at altitude to increase their red blood cell count and thereby enhance their aerobic ability. In 1972 and 1976 Frank Shorter lived in Boulder, Colorado, and alternated training at altitude with brief stays at sea level prior to his successful Olympic marathons. In contrast, Eastern Block athletes were then being drugged and doped. A study by Melvin Williams, published in 1981, showed an average increase in performance from blood re-infusion of about 10 seconds per mile for men running five miles in approximately 30 minutes (Williams, Wesseldine, Somma, and Schuster, 1981). This is slightly over a two-percent increase in performance and approximates the USATF’s allowance of three percent for the outdoor championship qualifying standards in events 1,500 meters or longer, and performances delivered at facilities at 4,000 feet or more altitude. An honest athlete simply cannot afford to give that much of an advantage to a competitor who might be training at sea level but engaging in these practices. Neither can an athlete living at sea level expect to compete on equal footing in the marathon against those who live at altitude and run on demanding terrain, such as the Kenyans. Athletes wanting to compete at the international level in the marathon need, at least occasionally, to train at altitude (See Chapter 13).

Marathon Equipment

As discussed in Chapter 10, the selection of athletic footwear can significantly affect competitive results. Sometimes it is possible to achieve a two-ounce reduction in shoe weight over a stock commercial racing flat, and this is worth at least a full minute in the marathon. There is also the question of whether the

spring stiffness of a given shoe is tuned to the individual's biomechanics and running technique. Again, Ned Frederick was able to demonstrate a change in oxygen uptake of approximately 1.3% in subjects running at racing speeds in NIKE AIR® racing flats, and such an improvement in running economy can be worth between one and three minutes in the marathon (Frederick, Clarke, Larsen, and Cooper, 1983). Adidas-Salomon AG introduced track spikes for the 2000 Olympic Games that claimed to provide an average improvement of 1.8% in running economy, and perhaps even as much as 4% (Nielsen, 2000). The author has also invented athletic shoes including carbon fiber spring elements that provide substantial improvement in running economy (U.S. 6,449,878). In brief, athletic shoes are undergoing a major transformation, but even the differences between any two conventional articles of footwear can be substantial. Athletes should select a lightweight shoe that provides optimal stiffness for their body mass and running technique, but also good heat dissipating qualities, traction, and overall performance for the anticipated environmental conditions.

As discussed in Chapter 12, athletes should test the apparel they would think to use or might be given as team issue. Despite the commercial claims, many so-called high technology fibers and materials do not perform well in the practical application: Buyer beware. Test the singlet both wet and dry in various environmental conditions to see how it behaves. A white singlet is generally best, and if direct sunlight and hot conditions are anticipated, athletes might wish to fashion a singlet with protection over the top of their shoulders, since this will reduce dehydration. Likewise, a white cap made of a material which does not retain heat, rather, includes vents, a visor, and an extension for covering the back of the neck can be helpful. The former Ironman Triathlon Champion Mark Allen made custom modifications to his apparel along these lines (Allen and Babbit, 1998). The right socks also need to be figured out well before a marathon. And given the various insoles used on racing flats, athletes should test their shoe and sock combination to really know if it works well. As discussed earlier, conventional athletic shorts with a restrictive inner liner may not help with heat dissipation and thermoregulation. And unless you expect to begin by running straight into the sun, do not use sunglasses, since they block the air stream from making contact with the area around your eyes. The head and face dissipate a significant amount of heat due to the high degree of vascularization in this area, and athletes are unwise to compromise this potential cooling effect.

Pre-Race Diet is Important

Athletes should make sure that their intramuscular triglyceride stores are not depleted going into a marathon. If athletes have been in hard training for several months, and do not sufficiently reduce their mileage two weeks prior to the marathon, then they may end up "hitting the wall." However, those who consume an adequate proportion of fatty acids from vegetable sources in their diet will less likely become depleted. Obviously, the use of intramuscular triglycerides as a substrate is even more important in competitive events having a longer duration, such as the Ironman Triathlon, or Tour de France. Accordingly, the intramuscular

Effect of diet on muscle glycogen content and duration of exercise*

Diet and conditions	Muscle glycogen content before exercise (μmol.g^{-1})	Duration of exercise (min.)
1. Normal mixed diet	97	116
2. Low carbohydrate diet for three days	36	57
3. High carbohydrate diet for three days	183	166

*Data from Bergström, et al. (1967)

TABLE 16.2—from Newsholme, 1983

triglyceride stores need to be maintained during training, and should be topped off starting about two weeks before the marathon event. In part, athletes accomplish this by easing their workloads during the worthwhile break associated with the ascent to peak performance. However, they also require a balanced diet, including approximately 70% carbohydrates, 20% fat, and 10% protein. Athletes should not consume an ultra high carbohydrate, low fat, low protein diet of pasta, including starch derived from wheat. Instead, they should consume adequate amounts of "hunter gatherer" foods, including fruits, vegetables and nuts. For example, athletes might also consume berries, grapes, cantaloupe, bananas, oranges, peaches, apricots, pears, apples, pineapple, dates, raisins, sunflower seeds, almonds, pistachios, avocados, beans, lentils, yams, whole grain rice, oats, and corn. When preparing food, use sunflower, safflower, or olive oil, which consist of monounsaturated or polyunsaturated fats. Humans are by nature omnivores, thus benefit from consuming meat occasionally, and also require the Omega 3 oils found fish (Cerutty, 1961 and 1967, Newsholme, Leech, and Duester, 1994, Autio, 2000, Coyle, Jeukendrup, Oseto, Hodgkinson, Zderic, 2000).

After the last time trial or so-called "depletion effort" three to five days before the competition, the primary dietary focus should be to successfully accomplish carbohydrate loading. An individual's available carbohydrate stores in the form of stored muscle and liver glycogen can dramatically affect his or her performance in the marathon. Table 16.2 illustrates the effect of various carbohydrate diets on athletic performance.

In this regard, athletes should not undertake the severe, so-called "depletion diet"—that is, a three-day carbohydrate depletion followed by a three-day high carbohydrate diet. This places a stressor on athletes at a time when the primary aim of the training program is to remove the same and facilitate peak performance. Athletes should simply "carbohydrate load" by maintaining a high carbohydrate diet, particularly during the last three to five days before the marathon. They should also make sure to stay well hydrated during this period. Do not make the mistake of waiting until the day before the event to start drinking